FLOODS-FLOOD CONTROL

A17

AMERICA NEEDS

A MODERN, INTEGRATED WATER ECONOMY

PART I

The Scientific Methods for True Flood Control, with Multiple Uses for Flood Waters for the General Welfare.

Bulletin 299

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Part I - The Scientific Methods are Successful.

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THE SCIENTIFIC METHODS
for
Prevention of Floods and Use of Flood Waters

Bulletin 217

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* * * *

FOREWORD

How to supply the needed quantity of water at the right place at the right time is fast becoming one of the world's major problems. And this is true not only for producing greater supplies of foods and fibres, but also as to meeting vast potential opportunities that are opening up, due to new processes and new industries. The main trouble in solving this problem is that we have been too prone to think that scarcity of water, or especially droughts, is something we can do nothing about.

Few persons have any adequate idea as to the stupendous aggregate of the actual losses of potential food supplies, incomes, etc., that are caused at one place or another each year by our failure to have the right quantity of water at hand when it is needed. Officially it was stated that crop losses alone in each of two states exceeded one hundred millions of dollars in the drought of July-August, 1944. Yet that drought seriously affected nineteen other states also in this country. During the writer's personal examination of many of the drought-affected crops in scores of places in nine Eastern states , it was learned that in all those areas, except two, an abundance of flood waters had been permitted to do great damage and then to escape during preceding months. In one of those states a great apple crop seemed assured in June; but soon the apples dropped off, due to lack of a little rainfall. Irrigation with impounded flood waters could have saved huge sums for that state, if the waters had been impounded by numerous cheaply made earth-fill up-stream dams. That is a lesson that India - "benighted India" - learned in six provinces several decades ago, and with such astounding success that one great European nation promptly adopted the "Indian plan" for river management and flood control; and some of the more progressive nations have sent commissions to study the Indian methods. The progress in hydrology made in parts of that country since 1801, has been said to constitute one of the world's most important steps in human betterment.

In view of our superior facilities for wide and rapid spread of important news, it seems a bit queer that so few Americans as yet have become aware of India's marvelous success for fifty years at solving a large portion of her flood troubles, while simultaneously increasing her food supplies, and also establishing new industries that have opened new paths to happiness for her people in several of the provinces. Also, all her investments of funds in this kind of flood-control have earned high interest each year.

The reason for the limited knowledge of these facts by Americans is that merited publicity has not been given in this country. The reasons will be found in Section II of this paper.

Our information on these matters mainly was gained in three ways:

(a) Through three years of intensive study on the official reports of the various Indian governments and of the British government regarding Indian affairs.

(b) Through correspondence with them or their officials; and

(c) From the data photographs and voluminous materials that kindly were supplied to us, on our request for accurate and dependable information.

To aid our readers in checking on all the statements contained herein, a selected list of authorities is included.

So deeply significant is much of this information that it is felt the time has come when it should be placed before all our people. Let us first consider very briefly some facts about India..

Very sincerely,

B. Ashton Keith, Director

Washington, D. C.
October 1, 1948

INDIA

A vast country with varied conditions, that in many respects are quite like our own. Rainfall varies from excessive in the east to almost none in the far west. Torrential rains flood many areas and at other parts of the year extremely dry weather kills the crops and causes famine. Multitudes have died of hunger in many years when the total annual rainfall was ample; but it did not come in the crop-growing season.

This great modern discovery -- the use and development of a modern, scientific management of waters -- came from the dire needs of suffering humanity, to learn better ways for using one of God's most valuable gifts, the waters of floods.

* * * *

ABSTRACT

This paper proposes the general need for an integrated, modern and truly democratic water economy. These suggestions are based not only on long practical experience, but more especially upon three years of intensive investigations on the official reports and other authoritative publications of this and eleven other nations. Some of these are listed at the close, with the call number of the U. S. Library of Congress.

Considerable information has been brought to light which we feel the common people, and particularly the taxpayers of our country, should know. There also are set forth the well-demonstrated success and the fundamental features of methods long recommended by men of science for prevention of floods with use of waters for the general benefits, instead of mainly for enriching a select few. Also, it compares this success with the long-time results of "fighting floods" both here and in the countries from which such methods came.

In the light of recent data on the financial returns on both sets of methods, two conclusions are stated, to which we, as taxpayers, invite your careful consideration.

1. Prime Importance of In-soak.

Even before the days of authentic history, some men(14) manifestly were impressed by the idea that nearly all living things on land depend upon ground-water levels being maintained(b) within the reach of roots of useful plants; and that nature cannot be depended on to maintain them. Traces of ancient canals in at least three countries show that nations long forgotten(35) found the best, cheapest and surest way to prevent famines and to meet the world's increasing needs (12) for foods and fibres, was through widespread promotion of in-soak.(c)

(b) Unchecked, deep gulleying may cause dessication of productive fields. Deepening of rivers by dredging also can promote crop failures in dry years.

(c) Infiltration of surface waters into the soil and sub-soil brings increased protection to crops in dry, hot summers, and stabilizes the flow of springs, creeks, and rivers, to the benefit of all industries.

2. The Methods of Scientists.

The first important characteristic of the scientific method for flood control, stream-management and water use is a general impedance of run-off by all feasible means, in or near the area of precipitation(48) or near it. The second is impoundment of surplus waters at high elevation as practicable, in order to make possible a very wide distribution(14) of the water by gravity. The third is large-scale diversion of flood waters from streams into "water transfer channels"(24-27) and canal systems by means of "barrages" or weirs. These long, low dams across streams are built with electrically-controlled gates or doors for the dual purpose of sluicing out accumulations of sand or silt, and to control the height of flood waters(25) in the stream. The fourth essential means employed by this method are large water-transfer "channels" (Many of them navigable)(28-2) for the six-fold purpose of (1) holding enormous amounts (d) of flood water, (2) transferring it in large amounts to dry regions or to distant storage reservoirs, (3) for providing additional waterways to aid navigation and (4) for supplying water and cheap power(27) to aid local industries.

The fifth means employed consists of intricate systems of canals to deliver water to farmers, and other users, of whom there are increasing numbers, due to new industries, and new processes. Several books(22, 25, 26, 27, 28) have appeared describing these marvelous increases in the improved provinces of India during recent years.

The sixth important means and increasingly used in this system is provision by the government of literally millions of "tub wells," or "bores," for supplementary or emergency water supply.

Three other features definitely add to the success of the scientific system and should be mentioned here:

Generation of electircal current wherever and whenever feasible(28-f), even by small plants. Although in-soak and widespread water-use come first, a surprising success (20, 25) has attended both the development of power and of local industries in regions using these methods since 1890, and particularly (27) since 1910. Rates on grid system delivery are as low as 1¢ per kilowatt-hour.(27)

One and one-half million acres of high desert land were changed into productive farms by tapping hidden sources of water by means of tunnelling into a mountain range.

Systematic drainage to prevent soaking the low lands. Recovery, treatment and re-use of part of the water. Extreme conservation and careful use also are important features.

3. The Fundamental Aim.

On later pages diverse officials will be quoted showing the primary purpose(26) is to protect and serve all the people and all the industries -- directly by supplying

(d) So effective are the "over-size canals" in controlling floods that China long has relied largely on such construction for flood control.

needed water for numerous uses; and indirectly (also in many ways) by making possible a wide-spread generation of cheap power - electrical current turned into a grid system for use wherever and whenever needed

Our earlier paper(10-a), "Recorded Results of Two Diverse Kinds of Water Economy," describing the scientific methods, was sent into all the States. Many private persons, officials and some institutions have requested further information. Some widely-circulated newspapers also have begun to print the data that have been brought to light through these investigations. Thus it may be seen that the Scientific System for river management has wide appeal.

4. Origin.

Combination of flood-water-retention and in-soak, with the prime purpose of general service, seems first to have been urged by several European scientists(e), notably by Sir William Herschel, who urged this as a fundamental feature of a truly successful water economy. However, the first (24, 25, 27) widespread actual use and development of these methods occurred in India, beginning 1801-10.

5. First Application.

Following two years of terrible summer droughts and famine that cost more than 1½ million lives, a young scientist of Delhi urged the European plans for water impoundment and general use on the crops of a small area. Quickly the plan was found to be successful - so successful in fact that a large cotton-buying concern began to supply both money and skilled men to aid in the further extension and use of these methods.

During the years 1837-8 great famines(26) were caused in several provinces that had not begun to use these methods. Lt. Col. Grant (18) in 1854 stated that the savings of crops, lives and property effected during 1837-8 by the use of these methods had amply repaid the grand total outlay. Then he urged more rapid extension of these works into other areas where losses in times of drought usually had been severe. The British Government had taken charge in 1851; but for nearly three decades extension of these works was hampered by unfortunate circumstances. Yet enormous extensions were begun around the close of the past century(18,19,20); and flood control combined with conservation and use of waters for the common good steadily has been expanded(19,22,23,24) until the outbreaks of the wars. At the opening of the last war, construction of large water transfer channels was being pushed at the rate of over 800 miles (26) per year. Later reports (1945) show that India now has over 79,000 miles of these large constructed water-ways, of which over 12,000 miles(30) can be navigated by ships.

6. The Earliest Purposes.

The first construction program in India(14) had the five-fold purpose of (1) providing some wages for people in want; (2) preventing future destruction by floods by impounding a large part of the run-off; (3) conserving the surplus waters for use of all, but particularly for growing food crops; (4) promoting in-soak that was adequate to maintain moisture in the soil and to stabilize the flow of streams; and (5) promoting general security by serving all the people equitably and by aiding all the industries.

(e) Arago, Kanitz, Marchand, daVinci, LeCoq, Home, Tchibataff, Blanqui, Dumas, Wex, et al.

7. Trends in Construction.

Due to changing conditions the main emphasis at different times has been placed on different parts of the construction program. The original aim in the Delhi area (14, 27) was construction of very many small-to-medium-size "tanks," or up-stream reservoirs to hold enough of the run-off from monsoon rains to meet the farmers' needs for irrigating their crops, and at the same time to prevent floods in one small river basin. The dams were mostly earth-fill and rock-fill; (14, 25) and many had rock facing. The height usually was from 20 ft. to 80 ft. from the bed of the stream; and the length of many was from 500 ft. to 1,000 ft., although a smaller number had other dimensions.

8. The Greater Value of Higher Sources.

Attention is called to the increased values of water that is impounded at higher elevations due to its possible wider distribution through transfer channels and canal systems. This means it can be made to serve more people, to aid more industries and to irrigate upper lands (21) that could not be reached by gravity delivery, if that water were impounded in down-stream reservoirs. For similar reasons, river sources of transfer channels may be far upstream. These phases seem always to have been kept in mind there during the past 140 years; but at some times, other kinds of construction received more active support.

9. Very high and costly dams not preferred.

Large dams such as we think of have been given comparatively less consideration (30) according to a special release by the British Censor. (G No. P9342, July 23, 1942) The construction of only one (fairly) large, high dam was underway in India; but there were four large low diversion dams or "barrages" each with systems of large "transfer channels," and canals. It was emphasized that only one very large high dam had been constructed in the preceding 20 years. For purposes of comparing their ways of expending public moneys for flood control, with some other ways, some of the principal facts will be stated.

10. Extreme Dimensions Rare in the Dams of India.

While there are other large works (both high dams and long barrages), they are not over-emphasized in this system. The following data may serve to give the reader a fair general picture of the relative less importance (28-g) of very large down-stream dams in the total of construction in a scientific water economy.

11. Some Examples -- a "High" Dam.

(a) The great Mettur Dam on the Canvery River in the Madras Presidency, is 214 ft. high and is nearly one mile long. The reservoir above covers 59 square miles. It supplements the irrigation of one million acres, and also irrigates a new area of 300,000 acres.

12. Some Examples of "Barrages."

(b) The Sardi system in Nepal has the longest canal system - 4179 miles; and 1500 miles of large water transfer channels, capable of discharging 5,000 cubic feet of water per second. That system irrigates more than 1½ million acres in a region where the average annual rainfall exceeds 100 inches; but most of it does not come in the growing season.

(c) The Lloyd barrage and canals near Sukkur in northwest India. There are seven channels of a total length 6,400 miles, and canals and other small distributaries

of total length 31,000 miles, irrigating nearly 6 million acres.

(d) The Sutlej System in the Punjab comprises 4 barrages -- all big works, second only to the Lloyd System mentioned above. Ten large canals or transfer channels take off above these great diversion dams. "Some idea of the importance of these works may be gained from the fact that each of these barrages commands an area bigger than the whole of the cultivated area of Egypt." /Statement taken from page 4 "Irrigation in India" from the British Censor (Quote No. P. 9342) 23-7-42./

(e) The Haveli channel takes off above the Emerson Barrage on the Chenab River in the Punjab. "This barrage has been designed on the latest principles, based on new theories worked out after years of experiment and study. The Emerson Barrage is nearly 3,000 ft. long and consists of 37 spans of 60 ft. and 14 spans of 30 ft. Water is held up to a height of 29 ft., an unusually great depth for such a work, founded on sand."

(f) The Periyor Dam in Madras Presidency has some unusual features: It was built under great difficulty in a narrow gorge, 3,000 ft. up in the Western Ghants where the annual rainfall averages over 120 inches. The catchment basin includes 300 sq. miles. The area covered by water is 12 sq. miles. The dam is 1241 ft. long and 155 ft. high, measured from the bed of the stream. By means of a tunnel one mile long, water is diverted from the Indian ocean eastward to the Waigai River, which takes the water 86 miles down to the Maduro district.

12. Some of their Discoveries.

Through the joint efforts of the Indian and the British hydrologists, several important discoveries (14, 27, 30) were made. Among them are the means and the methods for leaching out undesirable elements and minerals from the soil in some areas; for prevention of over-soaking, systems of drainage ditches, power-pumping, etc., are used with better than average success. In some areas, especially, their success at dewatering ground is enough to warrant the statement(25, 31) they are developing it into a science some of the over-soaking of the lower lands; for recovery, treatment and re-use of part of the water in some places; and tapping new sources of water supply by tunneling slightly upward into mountains. Add to these the basic discovery that it actually is possible to prevent floods and flood-damages to a very considerable degree through treating flood-waters, not as so much waste, but as a resource which now can be made to benefit all the people in many new ways.

Due to new scientific discoveries, new inventions and new industrial processes, there are now more than twenty valuable ways(10-b) of using surplus waters for general benefits. Also in addition to avoiding many enormous damages done by floods, amazing benefits, instead, are being derived, simply by diverting the surplus waters to far-distant water-users. Not the least important, is the discovery that standards of living in general have been raised simply by turning flood-waters to valuable uses. Thousands of factories and many new industries have sprung up in uncounted villages, towns and new settlements. Recent official reports show that even in India, many millions of people now are employed in new kinds of work that were not available only a few decades ago.

13. Merit of Credits.

Both the Indians and the British deserve credit also for the amazing financial success of the scientific methods for control of floods by impoundment and use of flood waters in the several areas where the necessary construction work has been completed. Having openly put the general welfare above all other airms, India now

finds she has more irrigated land than the grand total of all the other six nations that lead in irrigation; and that there is a steady earning of high average interest on the grand total of all the moneys expended to date -- both for "productive" and"non-productive" works.

Also, while using flood run-off to irrigate millions of desert acres, the average yield of crops is more than doubled by irrigation. Also, floods, droughts and famines, increasingly have been impeded. So effective are these methods that several Indian officials have stated that the savings since 1870 have exceeded the grand total of moneys expended from the beginning for the use of the scientific methods.

14. The Grand Total Cost.

According to Sir Bernard Darley(26), a grand total of £ 100,000,000 has been spent in India by the Government, on irrigation works of all kinds under British rule. And according to the 1933-36 Triennial Report, those acres were producing crops of £ 70,000,000 average annual value.

15. Enormous Social Values.

Dr. Anstey(26) states there has been an increase in the general prosperity, and especially among the agricultural workers, through several decades. It is uneven; but there is improvement in housing, utensils, clothing and savings. Also there are now alternative occupations, by which many can make a living apart from tilling the soil.

As stated by Dr. L. C. A. Knowles: "The irrigation works have made for security of life; they have increased the yields and the value of the land and the revenue from it. They have lessened the cost of famine relief; and they have helped to civilize whole regions. In addition, they now yield a handsome profit to the government.

16. The Recorded Earings of High Interest Annually for Fifty Years.

The following includes the lowest statement of earnings that have come to our attention. Nearly all, even the conservative Statesmans Year Books give figures that are somewhat higher through the past fifty years.

"The object of Government irrigation works was not to secure profits, but to abolish famine, and to bring prosperity and contentment to the people on the land. It cannot be expected that the more recent, costly works, such as the great Sukkur barrage system, will immediately show a profit on completion; - - - - but the incomes seem always to show an average around 5% on the total capital cost of all the government works."

17. Interest Paid on Prevention of Floods, Combined with those of Water Use.

These works are divided into "productive" and "nonproductive." A "productive"(24) work must show sufficient revenue to cover working expenses, and interest on the capital cost, within ten years of completion of construction. "Non-productive"(24) works are constructed primarily to protect precarious tracts, and to guard against periodical expenditure for famine relief. In 1938, the area irrigated by unproductive works was only 2,820,000 acres. The return on capital invested in the productive works was 14.99% in the Punjab and 5.32% in the United Provinces. In that year, the net return on all the government works, completed and uncompleted or under construction was 5.91%. Some say 7.95%, others still higher.

Some of the projects are very profitable. The Chenab Canal paid an average of 41% on capital cost during the first seven years, prior to 1921. The Godavari Canal System in 1919 and 1920 showed a return of nearly 25%.

But the social results are the main benefits. Also the water contracts with the users have a "no use, no pay" feature; and electric current increasingly is being supplied[27, 307] at rates as low as 1¢ per kilowatt-hour.

18. Glancing Backwards.

Thus it may be seen that, through employing the Scientific Methods of River Management and Water Use more widely since 1851, in six of her States and Provinces, India already has laid the foundation for veritable avenues for future progress, and in some fields that are new. This, despite the fact that only a few decades ago all those regions generally were included under the term "benighted India."

Recently an American authority stated that we in America, have seen only the infancy of the science of hydrology. But in India, due to more than fourteen decades of scientific experimenting and practical testing, there has been worked out a genuine science of hydrology which, in precisely the same years since Americans really began to employ irrigation (1857) has placed Indian irrigation not only ahead of ours, but also ahead of the combined results of all the six nations that have given irrigation the most attention.

19. Present Total Acreage Under Irrigation. (Encyc. Brit. Vol. 12, p. 692. 1946 Ed.)

1.	India	55,000,000 + acres
2.	United States of America	24,000,000 -
3.	Russia in Europe	8,000,000
4.	Japan	7,000,000
5.	Egypt	6,000,000
6.	Mexico	5,700,000
7.	Italy	4,500,000
8.	Spain	3,500,000
9.	France	3,150,000
10.	Java	3,000,000
11.	Chile	3,000,000
12.	Argentina	2,000,000
13.	Siam	1,750,000
14.	Morocco	1,500,000
15.	Australia	1,000,000
16.	China	1,000,000
17.	South Africa	800,000
18.	Peru	800,000
19.	Canada	400,000
20.	Algeria	400,000
21.	Philippines	250,000
22.	Hawaii	200,000
23.	British Guiana	100,000
24.	Cuba	50,000

And the industrial progress of India also is phenomenal.

20. Our Methods of so-called "Flood Control" were denounced and discarded by France in 1855, after long unsatisfactory use.

Even before the middle of the past century, the many advantages of the Scientific Methods of River Management and Water Use as demonstrated in some places in India

had become known to many of the scientists as well as the statesmen of France. Especially favorable were the reports showing greater economy and vastly greater efficiency in flood control.

Because of the increasing demands of their military engineers for larger and larger appropriations for dredging and dike building, the French government ordered a comprehensive investigation(39) on the progress that had been made (if any) toward diminishing expenses on the streams. This should have been the natural result if true flood control were being attained after long use of diking and dredging.

After long and careful study, their investigators reported that there seemed to be prospects only for increasing evil results and increasing expenses.

For these reasons, the French government announced their decision to discard (in 1855) the same kind of methods that Americans still permit to be applied for so-called flood control. And in 1857, after roundly denouncing the Roman or military methods as being both wasteful and inefficient, the French government adopted the Scientific Methods, as explained by J. Dumas(37).

Construction and other activities to promote widespread water-retention and insoak as well as wider distribution and use of impounded waters, began at once; but their too-cautious, slow expenditure of funds delayed the full benefits for several decades. Finally, around 1900, definite benefits became manifest. Flood disasters were becoming rare, soil erosion was diminishing, and dredging of streams was not increasing their expenses as fast as growth occurred in commerce and industries.

The French government reports on rivers and agriculture 1932-33, showed that of the total precipitation that fell on France during the ten-year period 1920-1930, only 1/640th of the waters ever got outside the stream banks to do serious damages.

That story is quite different from ours for the same decade. After having spent Midas fortunes for flood control in America, one flood in a single river basin destroyed more than(4) 1½ million farm animals and damages exceeded $300,000,000.

21. Looking Ahead in America.

The preceding partial description cannot adequately impress the vastness of the divergence between the Scientific Methods of Stream Management and Water Use, and the very old methods of Roman origin, which still are permitted to be used on the navigable rivers of this democracy, and which directly oppose the gravely important needs both of reclamation and of conservation.

The two services last named should no longer be forced to wage an up-hill battle to conserve the waters and to save our precious top-soils.

Of the approximately two billion acres in the United States, there are now only about 400,000,000 acres of really good soil; and all but one hundred million acres of it are subject to erosion. Dr. Milton Eisenhower (Pres. Kans. Agr. College) in Farm Policy Forum, pp. 13-15, (October, 1948) states that erosion is now costing us 3½ billion dollars yearly.

Officially it was stated recently that it is being carried away at the rate of $495,000,000 worth every year by one river alone. Also according to Dr. H. H. Bennett, Chief of the U. S. Soil Conservation Service, there are approximately 775,000,000 acres of less valuable soil, most of which also is being affected by erosion. "It takes from 200 years to 1000 years to farm topsoil a single inch

in thickness; and it is topsoil on which mainly we must depend for our crops. Any thinking person readily can see that we, like many other older nations that failed to save the topsoils, must face future want or even famines, unless we quickly stop every kind of rapid wastage of soils.

Despite their splendid results, the Soil Conservation office has admitted the job of saving the soils is only about 1/10 completed. Farms are being abandoned at the rate of several hundred every year, largely because of eroded and worn-out soils. We have forced the savers of our main resources (soils and waters) to fight an uphill battle by permitting all too much diking and dredging of our streams, when what is needed is not speed-up of run-off, but upstream water-retention by every practicable means, as widely and very successfully has been employed in six regions of India; and over all of France since 1857.

Much of our dredging and diking has been done under the pretense of "more flood control," but primarily to favor navigation. As ably shown by Wex(48) and by many others those means never have given true and permanent control of floods in any country; but on the contrary have led to increasingly rapid run-off, increasing erosion, increasing siltage of rivers with increase of expenses and flood-damage on the average of decade after decade.

22. Timely Recommendations.

It is our thesis that the time is at hand for America to have a modern and democratic water economy. In it there must be a harmonizing of methods everywhere to meet the needs of conservation and of all the people and all the industries. It should be so organized and integrated that all the agencies concerned can work along parallel lines and in the same direction.

It must function in ways that are compatible with democratic principles, not bureaucratic. In all such river basins as the Connecticut, San Joaquin, Platte Red, etc., the administration of a natural resource so vital as water, should most largely be supervised by duly elected representatives of the people of the affected area. This fully has been suggested and explained in our earlier publication "Plan for Fair and Democratic Local Management of Our Nation's Water Resources." (1947)

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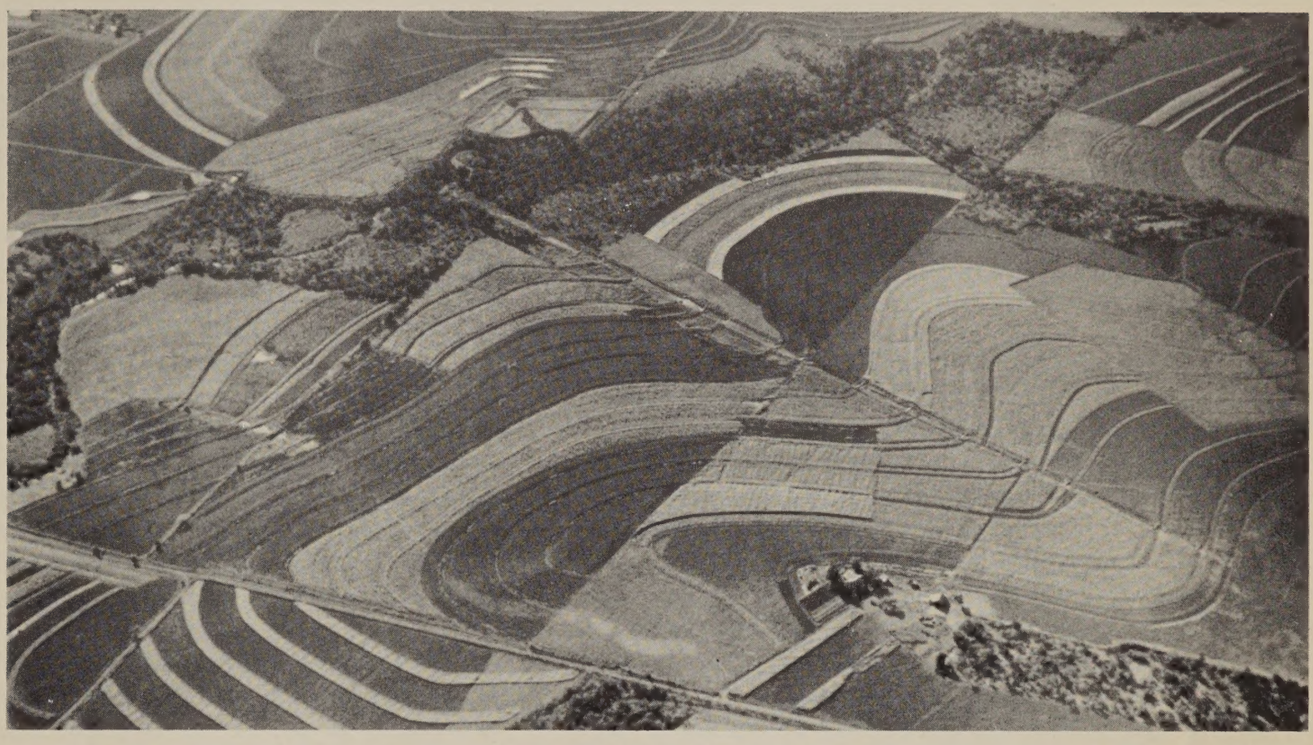
Flood Control

Begins at the Top of the Hill*



VIEW TAKEN OVER BEN WINKLEMAN FARM on Elm Creek watershed near Temple, in the Brazos river watershed, shows four farms saving their soil through the practice of soil conservation methods. The Tyler Experiment Station has shown that proper rotation with cover strip cropping reduces soil losses by as much as four-fifths as compared to clean-tilled cropping.

"FLOOD CONTROL must begin at the top of the hill where the first trickle of surface water starts." The late Roy Miller, Texan pioneer in the soil conservation movement and one of the founders of the Trinity River Improvement Association, believed this firmly. This principle underlies the whole flood control program now under way on this watershed. It is important, because Congress has selected the Trinity river as one of the first in the nation in which the flow of water will be controlled from the sources of its tributaries until it empties into the Gulf through a coordinated program of local and federal cooperation.

This elongated pear-shaped watershed extends about 300 miles north and south through what has been some of the richest farm land in the eastern part of the state. Never before has an attempt been made on such a large scale to reduce the crest of floods by holding back more water on the uplands where it falls and by retarding runoff of the remainder. In addition, the U.S. Corps of Engineers is now building huge holding reservoirs. These, together with existing structures, will have twice the capacity of the normal amount of water in Galveston Bay into which the Trinity river empties. As a result, barge navigation will be practicable to both Dallas and Fort Worth, located on its banks.

The Trinity river was the principal artery of commerce in East Texas before the Civil War. At that time the watershed was blanketed with a cover of grass and trees. Floods were not unknown in the early days, but for the most part they did little damage. The surplus water ran off slowly, and it did not carry the heavy load of silt with it that it does today. However, plowing up almost the last of the virgin grass land in the upper Trinity watershed to boost wheat production during World War I caused startling changes in the behavior of the river and its tributaries. They were further aggravated by the heavy cutting of timber and burning of brush. Runoff after a heavy rainstorm now requires only days where it used to take weeks.

East Texas has an unenviable record for both intensity and duration of rainfall and it is also subject to lengthy and severe drouth. Big floods usually develop in the winter or spring when rains fall for a long time over a wide area—often over the entire 18,000 square miles of the watershed. In most years the Trinity stays above flood stage for 75 to 100 days at 40 miles above its mouth. Small but destructive floods arise from sudden heavy local rains along its tributaries, often when the soil is moist and cannot soak up water. An average of 46 such flash floods occur in the watershed annually.

With this heavy runoff of water has gone much of the good topsoil from productive farm lands. Since the beginning of cultivation, 50 to 75 years ago, it has been calculated that approxi-

THIS SPECTACULAR EXAMPLE of gully erosion is in the Cross Timbers section of Wise county. It had to be abandoned as a farming area and will be planted entirely to grass. During the first 15 to 18 years this land was in cultivation, it produced nearly a bale of cotton to the acre and 60 bushels of corn.

mately 1.9 million acre feet of soil have been removed from the upland area of this watershed. To haul this amount of earth would take 1½ billion trucks, or a solid line that would reach 210 times around the earth at the equator. Once erosion had begun, the rate of loss was accelerated and farmers have paid a heavy cost by reason of reduction in the productivity of fields, pastures and woodland. Farm incomes have been lowered by millions as a result, and in certain critical areas 50 to 90 percent of the surface soil has been removed by sheet erosion and numerous gullies have been formed to a depth of 20 to 30 feet.

By-products of surface runoff at the top of the hill and of resulting soil erosion are sedimentation of fertile bottom lands and filling up of stream channels. Nearly 117,000 acres of valuable flood plain lands have been seriously damaged by such deposits of coarse materials eroded from the uplands. With increasing ftequency of floods many scores of thousands of acres of fertile bottom lands have been necessarily abandoned for cultivation. An erosion survey has revealed that the tremendous loss of soil and rapid runoff of water from tributary watersheds are largely avoidable by proper land use.

A top-of-the-hill program to correct these evils involves the following:

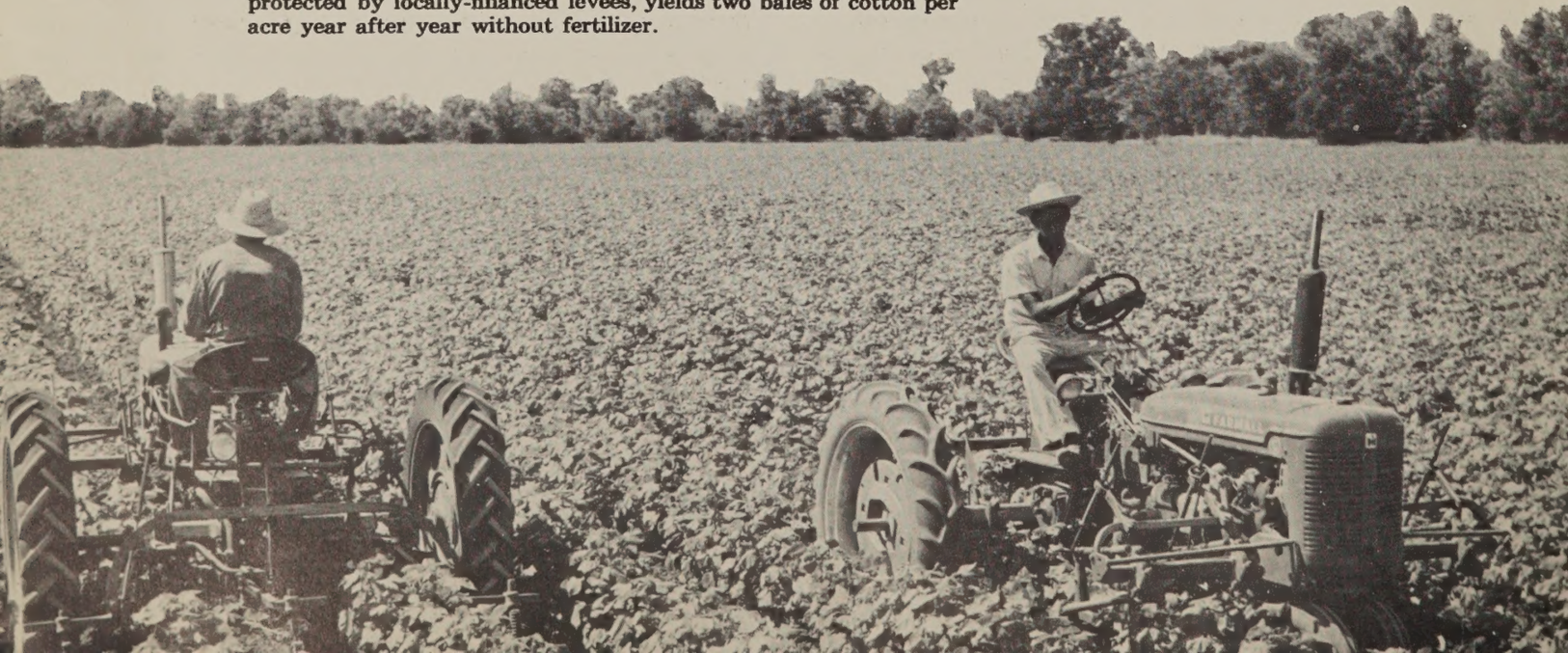
(1) Conversion of land to the use for which it is best adapted from the standpoint of the long-time profit and protection of the soil.
(2) Improvement in the cropping system.
(3) Improvement of pasture, meadow and forest cover.
(4) Installation of mechanical structures.

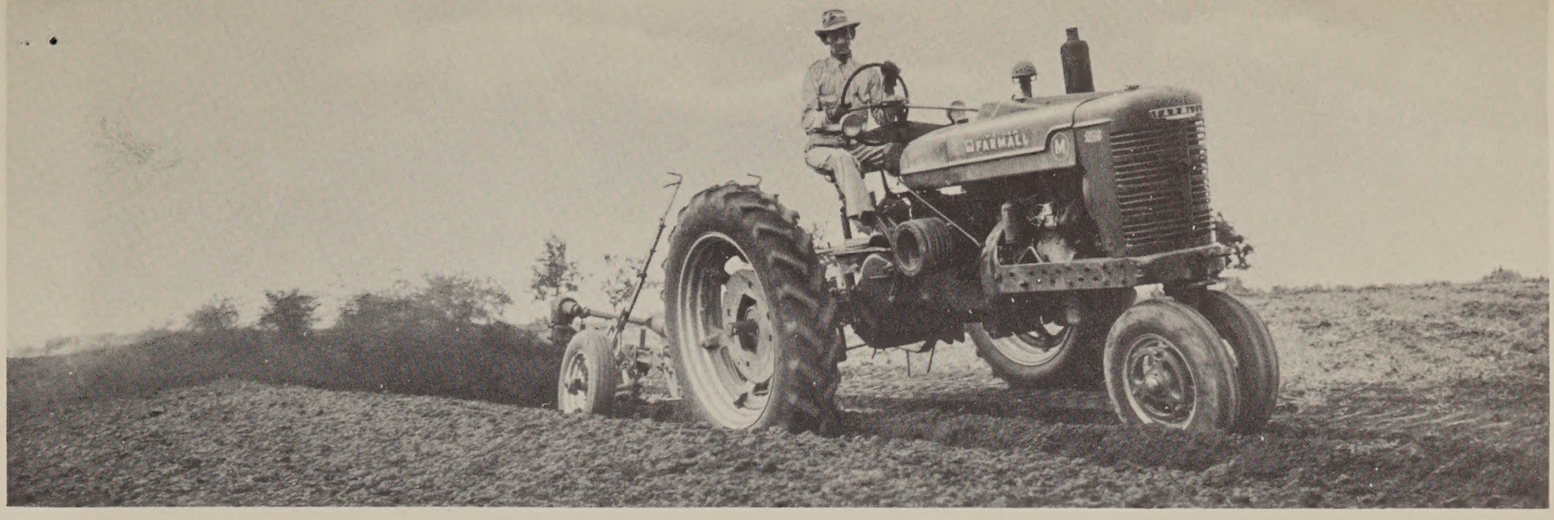
Primary responsibility for carrying out this upland program has been delegated to the U.S. Soil Conservation Service. Within 10 years or so, some 8 million acres of the upper Trinity watershed will be treated to hold water and retard runoff beyond the ordinary requirements of soil conservation. As the entire area is now organized in soil conservation districts, plans will be made on a farm unit basis with full recognition that they must fit in with the economic needs of those who own and work the land. When a farm conservation plan has been developed that is acceptable to the individual owner and provides adequate erosion control, a voluntary agreement is made with the soil conservation district to carry it out. This agreement is under the control of local supervisors who will cooperate with responsible state and federal agencies in carrying out the provisions of the Texas law and 1944 authorizations under the over-all federal Flood Control Act of 1936.

Since 1946, rapid progress has been made in the reduction of flood damage through the combined application of conservation measures on upland farm and ranch lands. The farmers who sustain 90 percent of the present annual losses will benefit most from this top-of-the-hill program. It is estimated that they will gain $3.19 for each dollar's worth of conservation work done.

On 454 farms in the blacklands section, where the conservation program has been in effect two or more years, grazing land was increased by 62 percent and crop land was reduced by only 10 percent because 2,400 acres formerly idle are now productive. However, the average increase in production per acre was 21 percent for cotton, 37 percent for corn, 13 percent for grain and sorghum and 37 percent for forage crops. Studies made on conservation-treated farm lands following torrential rains in 1949 showed that where farmers had protected their soil by the combination of recommended practices there was no appreciable damage even in the area of the heaviest rainfall. On the other hand, untreated cropland, especially in row crops, lost many tons of topsoil an acre.

WILLIS AND MC DANIEL cultivate cotton on F. E. Pollan's Bois D'Arc island farm on the East Fork of the Trinity. Reclaimed bottom land, protected by locally-financed levees, yields two bales of cotton per acre year after year without fertilizer.





C. L. SIMS, McKinney, builds a terrace on the 244-acre farm of Mrs. W. T. Hoard, located in the East Fork subwatershed, with the Farmall M and the Whirlwind terracer. Sims operates this farm and is carrying out a complete coordinated program with the Collin County Soil Conservation District.

This was mainly by sheet erosion but also by gully washing. Combined damage to unprotected land and crops was $13.40 an acre in the area of most intensive rainfall and $6.08 per acre in areas of less intensive rainfall.

Detention structures will play an important part in retarding runoff from local storms. These will catch the water and release it gradually so that the smaller streams do not overflow. The first completed detention structure in the watershed proved its value in the first heavy rain when two inches of rain fell in one hour over the drainage area. Construction of additional structures had also been started last June in both the East Fork and West Fork sections. On the East Fork subwatershed, 107 detention structures will be built to retard runoff from 472,000 acres. These will be engineered to release a flow at a rate not greater than 5 cubic feet per second for each square mile of drainage area. This is in contrast to a former peak flow exceeding 1,200 cubic feet per second per square mile of drainage area.

It is realized, however, that these detention structures, ponds and other structures, together with soil conservation measures applied by farmers, cannot eliminate entirely big floods along the main stem of the Trinity. The United States Army Corps of Engineers is constructing four large dams and reservoirs to impound up to 3½ million acre-feet of water. They will provide storage for flood control and also provide water conservation for municipal, industrial, agricultural and navigation uses. Increased flow during low water periods will produce other benefits in the lower reaches of the Trinity, such as abatement of sewage pollution and prevention of salt water intrusion.

Complete control of water resources in the Trinity rivershed is fast becoming a reality because of the spirit of self-help and accomplishment by Soil Conservation Districts and local interests. Many improvements have been made over a period of 35 years to solve surface water problems without either federal or state aid. Locally built reservoirs already have an aggregate capacity of water storage in excess of two million acre-feet. About 500 miles of levees have been constructed and maintained to make possible the reclamation of 250,000 acres of fertile bottom land as well as giving cities on the Trinity much-needed protection.

The Trinity Improvement Association sponsors a coordinated program for the entire watershed. This includes flood control, soil-water-forest conservation, navigation, reclamation, alleviation of stream pollution, conservation of wild life and storage of water for municipal, agricultural and industrial uses. The East Fork Association has been working for some years to improve the 680,000 acres in this subwatershed. It helped to achieve the organization of the Collin County Soil Conservation District and later was instrumental in obtaining 105,000 acre-feet of water conservation storage in the Lavon reservoir, the cost of which will be financed by the six towns that have formed a water district to make use of it.

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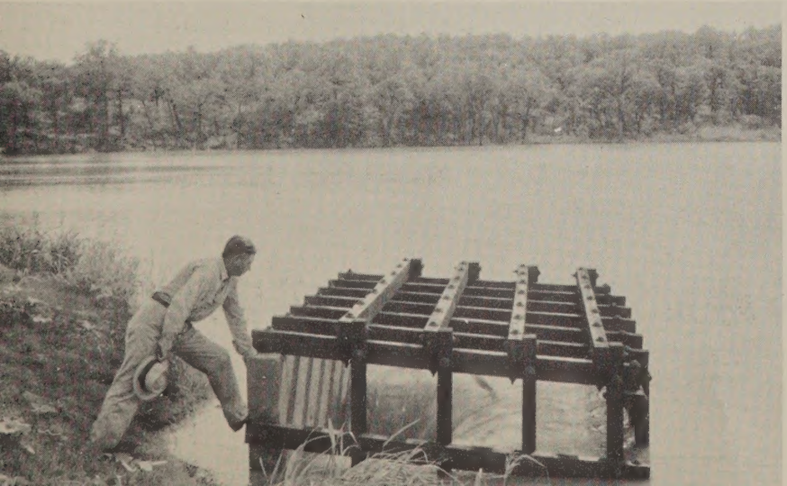
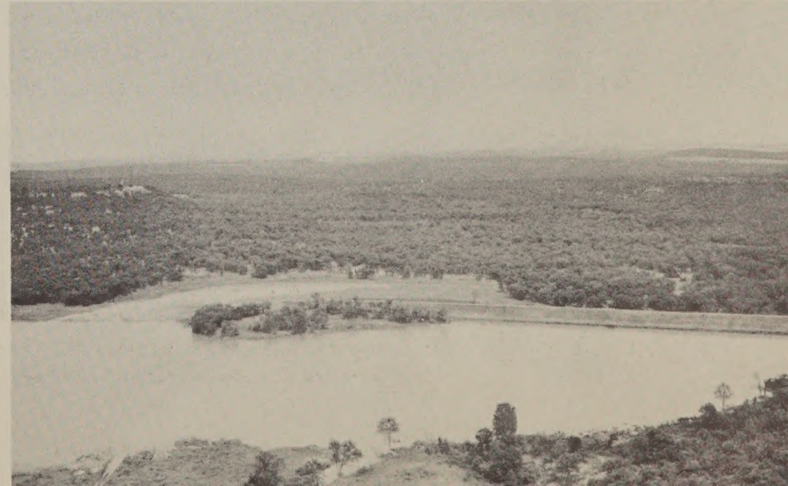
*Most of the facts and photographs for this article were supplied by the U.S. Soil Conservation Service, Fort Worth, Tarleton A. Jenkins, chief, Information-Education Division; also by the Trinity River Improvement Association, Fort Worth, Forrest L. Park, engineer.

REGIONAL ENGINEER J. J. COYLE inspects debris trap over concrete drop inlet riser behind Howard Creek dam after storm. Concrete box culvert carries off under the dam the quantity of water creek channel can safely carry away.



NO. 1 DETENTION STRUCTURE on the west branch of Howard Creek, a tributary of the upper West Fork of the Trinity, showed its value in first big rainstorm. Water in reservoir at top level was 11 feet below emergency spillway.



Pattern for a Brighter Future

Thousands of our farms have a new look these days. The patchwork pattern of square fields, that invites erosion, is giving away to a new soil-saving design. More and more of our crops are growing in swirling strips and flowing contours that hug precious topsoil to sloping land.

Many of these farmers are farming on the contour, fighting soil erosion, with their *regular* Farmall tractors and McCormick implements. But, International Harvester is doing more to help farmers win their battle with wind and water than merely to provide farm machinery that's well suited to soil conservation practices.

A special IH task force is tackling erosion control and other tough farm problems. We call this section of our company Farm Practice Research. Here are some of the things this group of farm specialists is doing:

1. **Studying soil and water conservation problems**
2. **Research in soil analysis and land rebuilding**
3. **Research in methods of applying fertilizer**
4. **Research in handling new field crops**
5. **Studying land use trends**

Our Farm Practice Research Section works with farmers . . . with local, state, and federal agencies. It gladly cooperates with anyone interested in saving our soil and developing a more stable and prosperous agriculture. International Harvester Company, Chicago 1, Illinois.

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CR-264-B. 1-21. Lithographed in United States of America.

November 15, 1947

FLOODS-FLOOD CONTROL

FLOOD CONTROL ON THE POTOMAC WATERSHED

by
George R. Phillips, Office of the Secretary
U. S. Department of Agriculture

I appreciate being invited to participate in the Conservation Forum sponsored by the Staunton-Augusta County Chamber of Commerce in the interest of proper use and management of the resources of the upper Shenandoah River watershed.

Your idea of considering, at one time, many of the aspects of conservation of the basic resources of this area is in keeping with the kind of planning approach provided for by the Flood Control Acts and designed to yield effective basin-wide results in floodwater and sediment damage reduction. Similarly, it is in keeping with the experience of land owners and operators in other watersheds who are finding that, by all working together in community-wide efforts to do a thorough job of installing the measures included in a watershed improvement program, the best results are obtained for them individually and for the watershed as a whole.

The route over which I drive from my home to work in the Department of Agriculture carries me by a stretch of the Potomac River. Day after day I see barges carrying sand and gravel from a downstream point to a building supply plant in Georgetown. That sand and gravel came from the watershed lands of the Potomac River and its tributaries and was carried there when the river was in flood. Accompanying it, but today unseen and lost forever for use by the occupants of the watershed, was a tremendous volume of fine silt and clay particles, organic matter,

FLOOD CONTROL

FLOOD CONTROL ON THE POTOMAC WATERSHED

by

George R. Phillips, Office of the Secretary
U. S. Department of Agriculture

I appreciate being invited to participate in the Conservation Forum sponsored by the Shenandoah-Augusta County Chamber of Commerce in the interest of proper use and management of the resources of the upper Shenandoah River watershed.

Your idea of considering, at one time, many of the aspects of conservation of the basic resources of this area is in keeping with the kind of planning approach provided for by the Flood Control Acts and designed to yield effective basin-wide results in floodwater and sediment damage reduction. Similarly, it is in keeping with the experience of land owners and operators in other watersheds who are finding that, by all working together in community-wide efforts to do a thorough job of installing the measures included in a watershed improvement program, the best results are obtained for them individually and for the watershed as a whole.

The route over which I drive from my home to work in the Department of Agriculture carries me by a stretch of the Potomac River. Day after day I see barges carrying sand and gravel from a downstream point to a building supply plant in Georgetown. That sand and gravel came from the watershed lands of the Potomac River and its tributaries and was carried there when the river was in flood. Accompanying it, but today unseen and lost forever for use by the occupants of the watershed, are tremendous volumes of fine silt and clay particles, organic matter,

and plant food that passed on downstream to be deposited as mud flats or on the ocean floor.

This process of detachment of soil particles by beating rains and uncontrolled run-off from watershed lands and their transportation downstream by floodwaters has, of course, been taking place for a long time. Our interest in it, from a floodwater and sediment damage standpoint, has to do with the period since the white man's occupancy of the watershed. During these years the erosion process has been greatly accelerated and extensive flood damage has been done to fields, to highways and railroads, to towns, and to the bottomlands along the Potomac and many of the streams tributary to it. Our particular concern at this time has to do with what may occur in the future and what we can do now and henceforth to improve the condition of the watershed so that damages by floodwaters and sediment will be reduced.

The flood control problem in the Potomac River basin is one unit of the whole national flood control problem which faces our country today. That national problem must be tackled watershed by watershed. Eventually, we hope, all the Nation's watersheds will be in such condition and will be used and managed so that flood damages on them will be greatly reduced and so that floods will not constitute major hazards to the continued occupancy and productive use of watershed lands.

Similarly, the watershed improvement job in each of the minor subwatersheds within the Potomac basin is a unit of the whole Potomac River watershed improvement job. Appropriate measures, planned for each minor subwatershed as a unit, and related to the over-all plans for the

basin as a whole, must be installed in these subwatersheds in an order of priority that will yield fastest and most effective results for the watershed as a whole.

We can learn much for the guidance of our work in the years ahead from a study of a watershed and an analysis of what has occurred in the past. The Watershed Survey Report on the Potomac River watershed prepared by the Department of Agriculture, under the authorizations of the Flood Control Acts, with the help of many interested local individuals and organizations, contains valuable data on this subject. The watershed improvement program it presents and recommends, and which the Congress has approved and authorized the Department of Agriculture to participate in, is based on an analysis of past experience and on judgment as to what should be done in the future. Additional experience with its installation, and performance within minor subwatersheds where measures are first installed, will demonstrate its adequacy or shortcomings and form a basis for adjustments if they are needed and justified.

Flood control begins where rain falls. It ends, for any given watershed, where the water leaves its lowest point. Rainfall, responding to the force of gravity, endeavors to make the journey from where it strikes the earth to where it leaves the watershed by the easiest and fastest route. The faster it travels, the greater are the probabilities that it will concentrate in quantities sufficient to create floods. Also, the faster it travels, the greater are its scouring and silt carrying capacities. Consequently, the ability of flood waters to cause damage is closely related to their rate of run-off and, of course, to their volume.

It is thus quite evident that the watershed improvement job in aid of flood control on the Potomac watershed or on any similar watershed, large or small, consists of (1) causing a maximum amount of the rain that falls to infiltrate into the soil where it can be temporarily stored, and (2) of routing and controlling the surplus which runs off so that it will travel slowly and carry a minimum amount of silt from the surface of the soil and from gullies and channels into the main stream.

While the Potomac watershed was entirely clothed with forest cover, nature provided the best possible means for effectuating maximum infiltration of rainwater into the soil. The energy of falling raindrops was dissipated as it fell upon the leaf mulch covering the surface. The water then seeped down through the leaves, litter and decaying organic matter into the soil. Considerable amounts were temporarily stored there and later released through springs and by transpiration through trees and shrubs. Nature also provided an effective means to retard the run-off of the surplus that was not absorbed, together with that quickly returned to the surface from shallow soils, for it slowly wound its tortuous way downhill through and over the delaying leaf mulch. Erosion from the watershed was held to a minimum, for mineral soil was not exposed over large areas, except where fires occurred. The sediment load of streams was limited principally to silt scoured from the channels and from caving banks at flood time.

Such portions of the presently forested parts of the watershed as are now properly managed to maintain a good soil cover of decaying

leaves and twigs still perform their functions of aiding maximum infiltration and preventing erosion just as they did before the white man came. In this connection, we must remember that, just because trees or shrubs are growing on land, it does not axiomatically follow that the soil beneath them will readily absorb water. If the forest is burned over or is grazed by livestock, the surface soil may be so compacted by beating rain or by trampling hooves that its ability to absorb rainwater and to retard run-off will be low. However, it is not mandatory to have a forest of large trees for effective watershed protection. It may even be disadvantageous unless there is a good ground cover beneath them. Density of crown such as is provided by small trees and shrubs is important, particularly near the ground, to check the force of beating raindrops if a surface mulch has not yet accumulated. Development and maintenance of the mulch to cover and protect the soil surface so it will readily absorb water and so it will not erode is most important of all.

Clearing of large portions of the watershed and heavy over-cutting, destructive logging, burning and grazing of extensive forested areas has created conditions much less favorable than previously existed for infiltration of rainwater into the soil and for retardation of the surplus which seeks a quick way into the stream channels. Such clearing has been a part of the white man's procedure for adapting the watershed lands to meet his varied needs. It is up to man, since he must use these lands, to devise and apply measures that will keep them intact and retard run-off from them. A considerable population is dependent

upon them for a livelihood and they form an important part of the Nation's farm and forest production plant.

Basic to maintenance of the watershed lands in stable condition is the need to use them in accordance with their use capabilities as determined by soil type, slope, resistance to erosion and other factors and to apply appropriate conservation and management practices in carrying on farming and forestry operations. For the watershed as a whole this is a somewhat complicated job, but it is good business for the farmers and forest owners whose land is involved, for the measures fit in well with conservation measures designed to retain and build up soil fertility, make farming operations easier, and increase production. For any given farm or forest property it may be a relatively simple job, involving only the adoption of recognized good management practices. In other cases, additional measures may be needed.

The owner and operator of each acre of cultivated, pasture and forest land in the Potomac River watershed has a responsibility to himself, his children and his neighbors to so use and manage his lands that they contribute to accomplishment of this watershed protection job to the maximum extent consistent with their proper use as producers of agricultural crops, livestock and forest products and to provide recreational opportunities.

Local, State and Federal Governments also have responsibilities of varying degree to help accomplish this watershed protection job. Some publicly owned lands are situated within the watershed, various improvement measures affect more than a single property so a community or

broader interest is involved, and the Department of Agriculture and other public agencies are authorized to furnish various types of assistance to help accomplish the job in the public interest.

The Congressionally authorized watershed improvement program recognizes these various responsibilities and sets the stage for all to participate according to their interest and abilities in a single watershed-wide effort.

The Department of Agriculture's Survey Report, upon which the program is based, delineated the watershed into five so-called "problem areas" within each of which the conditions encountered and the measures recommended were somewhat uniform, but different from those in the other problem areas. Problem area #3, within which we are meeting today and comprising 27 percent of the total watershed, was designated as the Upper Shenandoah River Watershed and includes that portion of the watershed above Front Royal.

When work plans for carrying out the actual watershed improvement job in aid of flood control were started early in 1946, the Upper Shenandoah was delineated into its five natural tributary watersheds as a first step in establishing priority for work in this problem area. Those tributary watersheds are (1) South River, (2) Middle River, (3) North River, (4) the South Fork of the Shenandoah River below the confluence of the North, Middle and South Rivers, and (5) North Fork of the Shenandoah River.

These tributary watersheds were further delineated, for the purpose of planning and installing improvement measures, into a large number of

natural minor subwatersheds such as those of Upper Middle River, Back Creek and Naked Creek.

Selection of the minor subwatersheds in which to initiate work, within each of the problem areas, was made by the Soil Conservation Service and the supervisors of the soil conservation districts in the areas. The principles governing the selection of these first subwatersheds, and of the others making up a tentative twenty-year work schedule, were their location with respect to the tributary into which their waters flowed, their topography, and their representativeness as regards types of farming, land utilization, degree of erosion, flood problems and farmer interest.

The work plan for each subwatershed provides for the intensified application of conservation practices and measures which contribute directly to the reduction of flood volumes by increasing infiltration of water into the soil and which reduces erosion. They include vegetation of certain lands with grass or trees, contour farming, strip cropping, improvement of pastures, application of sound pasture management principles including proper season of use and proper numbers and distribution of livestock, protection of woodlands from fire and livestock grazing, adoption of proper cutting and logging practices, and other measures.

Each subwatershed work plan also provides for orderly disposal of water in conformance with the water control pattern for the entire watershed. It shows the kind and location of each measure and practice needed to carry water from the fields and roadsides down to the stream

channels with a minimum of damage from erosion and flooding, together with their order of installation correlated to the entire system of water control. Included are grassed waterways and gully, streambank and channel stabilization measures.

The rate of establishment of the various measures has been charted so that the work in each subwatershed should be essentially completed in three years.

Certain of the measures, such as channel stabilization, which involve two or more ownerships will be installed on a subwatershed basis without regard to property lines but under cooperative arrangements between all involved. Other measures such as pasture improvement, contour farming and strip cropping will be applied on a farm by farm basis within a subwatershed.

Fire protection will be established and maintained on State and privately owned lands by the State Forester, in accordance with his over-all plans for State-wide fire control and the protection standards required for flood control purposes within the watershed, with the cooperation of local units of government and the Forest Service of the U. S. Department of Agriculture. The State Forester, with the cooperation of the Forest Service, will make the services of foresters available to woodland owners to help them in estimating, harvesting, and marketing their timber and properly managing their woodlands for watershed protection purposes. The Forest Service and the National Park Service will maintain fire control on national forest and national park lands respectively and will appropriately manage these lands.

Much of the work of installing the various measures on farm lands will be done by the owners and operators of the lands upon which they will be installed and which will be benefited by their installation. Technical and other assistance will be furnished by soil conservation districts, which have local responsibility for much of the work, and by the Soil Conservation Service of the Department of Agriculture.

In its contributions to the work, the Department of Agriculture will place emphasis on the application of measures to correct community problems and which will produce benefits of major importance both in and below the community involved.

Flood control conservation practices and measures planned on a natural subwatershed basis and applied cooperatively by groups of land owners and operators will also have high priority in the use of funds the Department may have available.

Installation of the watershed improvement program authorized by the Congress was estimated to be a 24-year job. Completion of the job in a shorter time will be to the advantage of all concerned. The watershed will have been damaged to a lesser extent by erosion and uncontrolled run-off and the benefits of protective measures will become effective sooner. This will be evident in those minor subwatersheds where measures are first completed.

In order that we do not expect too much from watershed improvement work in aid of flood control, especially as it affects the downstream reaches, we should recognize its limitations as well as its benefits.

The program will greatly reduce the number of small floods and the flood damages caused by those which do occur on many tributaries and will keep much sediment from the larger streams, but it alone will not protect the lower reaches when the major floods occur. No matter what the watershed lands are used for in the future and how skillfully they are managed, we can still expect that from time to time rains will occur of such intensity, extent and duration that the run-off from them will cause flooding of lands along the Potomac River and its principal tributaries unless adequate main stream engineering works are constructed to regulate and confine the flow of the floodwaters.

Installation of the flood control program is a progressive, cooperative job with a major responsibility for its installation, and particularly for its maintenance, resting on the people within the watershed. The Conservation Forum you are conducting today will contribute materially and constructively to a broader and more detailed understanding of the problems involved and benefits expected by the people directly affected. That is fundamental to the energetic, cooperative action which is essential on the part of all concerned if the flood control and other conservation objectives you envision are to be expeditiously attained.

1.33
(1196)

Orig. draft sent
Carl Ford, Planning Div.
SCS. Wash. DC - with
memo from WLC - 1-4-55

FLOODS IN THE UNITED STATES

1. The Flood Problem

Floods occurred before man's occupancy of this nation began. We are not entirely innocent of increasing the ravages of flows through our activities with fire, axe and plow, but generally speaking, we did not create floods. Rather, the problem has been intensified by our contesting nature's delegation of certain lands to floodways.

Settlement invaded the country along stream routes. Transportation, power development and water supply, the basic necessities of agriculture, could be adequately satisfied on the stream banks. Agriculture spread over the adjacent areas but the need of water power for processing agricultural products confined industry to the banks of streams. Shipping of raw materials and the return of processed goods also encouraged congregations along the waterways.

As new modes of travel were originated, routes were laid down along water-courses to take advantage of the flat flood plains and to connect established populaces. In the uplands, farm operations were centered upon small creeks. Here again water supply was a basic necessity. In addition, the rich alluvial and colluvial deposits adjacent to streams were highly productive. At present, it is estimated that more than 5 percent of our agricultural lands are on the flood plains of small streams. As operations, installations and investments developed and grew, these flood plains became more and more important to our national economy. A high proportion of the industries located thereon are now considered vital to our defense. Flood damages have been consistently and rapidly rising for a number of years; not because of increasing flood volumes, but because of development and increased evaluation of the flood plains inundated.

II. Factors Affecting Floods

The tributary drainage systems in evidence today are the results of centuries of activity by the elements upon the original conformation of our land surface. The southern edge of the glacial drift sheet, for example, is slightly north of the Ohio River on the eastern side of the Mississippi and slightly north of the Missouri River to the west. Water from the melting glaciers followed the slopes and cut the beginnings of a drainage system. Since

that time flows produced by excess rainfall have eroded and redeposited soils and materials to alter the original drainage pattern. In Geological time-units there have been changes in the climate of various sections of our country; areas which are now arid or semiarid had excessive rainfall at one time. Drainage systems cut during that era are much greater than could logically be attributed to present rainfall in these areas. Due to variations in gradients, erodibility of soils and rock materials, and to variations in the occurrence of flow events, the efficiency of these drainage systems did not develop equally in all portions. It is impossible to establish a single pattern of behavior for all drainage areas, therefore,, discussions must consider the most usual rather than the precise.

Rainfall, more than any other single factor, determines the characteristics of a flood. Flood magnitudes are the result of rate, duration and areal extent of rainfall upon existing conditions of the land. Point rainfall is greater than average rainfall over a sizeable area. That is; there are storm centers in which rainfall is greater than it is in the surrounding areas. The path or direction of movement of the storm center will, as discussed later, greatly influence the magnitude of any resulting flood. High intensity "cloudburst" type of storms are usually of short duration, are localized and occur in the hot season. The so called "general" rains of great areal extent are of less intensity but longer duration than the "cloudburst" type of storm and occur mostly in the cooler seasons.

Flows from small drainage areas respond more quickly to rainfall intensities thando the flows from large areas because of the shorter distances of flow. This, together with the higher rainfall intensities on small areas, causes relatively higher peak flows per unit area from small watersheds. It also leads us to expect floods from small areas during hot-season "cloudburst" storms and floods from large areas during cool-season long durated rains. Occasionally a cloudburst storm will travel a path which follows the direction of drainage for a large area. A series of small-area floods thereby contributes to flow in the main stream and if the storm travels at a speed which causes coincidence of confluence of flood flows from these small tributaries, a major flood may occur on the main stream. A vast majority of these hot-season storms are extremely localized or their path does not coincide with a large drainage way to produce major floods hence; in general, large area floods occur during long durated storm periods.

Floods originate as excess rainfall, consequently, the nature and condition of the lands upon which the rain falls is extremely important. About one fifth of the volume of an agricultural soil is air space which can be occupied by water. The top foot of a good agricultural soil has storage space for approximately 2.4 inches of rainfall equivalent, but several factors may limit the utilization of this storage during any particular storm: Antecedent rainfall may have previously filled this storage, the soil may be in such condition that surface intake is very slow, rainfall may be at an extremely rapid rate or land slopes may be such that excess rainfall is removed very rapidly with only short opportunities to infiltrate.

The term "flood" is not synonymous with some specific rate of flow. What may be a flood at one section of the stream may be well controlled flow at another section. Flooding will result from a reduction in channel capacity due to any one of a number of physical conditions such as a reduction in gradient, barriers to flow, meander or changes in direction, an undefined channel or siltation of a channel. Flooding may be induced at one section through upstream changes in the channel which tend to speed up flow. For example, the removal of some barrier by force of the flow or improvement of the hydraulics of a reach through scouring may speed up flows to the extent that subsequent sections downstream are not adequate to carry them. Thus the flooded section may shift over a period of years from one place to another along a stream bed which is not stable.

Confluences of tributaries are potential flood areas. As already mentioned, the synchronism of flows from tributaries may be induced by storm travel and result in flood flow from a local storm. On a larger scale, the flood works at the confluence of the Missouri River with the Mississippi north of St Louis, Missouri and of the Ohio River with the Mississippi at Cairo, Illinois, are exemplary efforts to control the floods which occur when tributary peaks coincide with peak flows on the main stem.

III. Flood Control

Flood control measures must be adapted to the location and to the drainage area above. Volumes of flow in the main stem of great rivers are so large that it is not feasible to store any appreciable fractions of the total flow. Sometimes it is possible by the use of gates to hold a reservoir in reserve to be

filled during the crest of the flood flow, thereby lowering the crest stage in the channel. Such installations are very costly and their success is dependent upon the duration of the flood crest. The most usual effort is toward speeding up the flow into the ocean, bay or gulf by channel improvement, by confinement of flow with levees or by auxiliary cut-offs or canals to provide additional capacity for flow. The flood works at New Orleans and the levees at Cairo, Illinois and St Louis, Missouri, typify main stem controls.

At some point in the tributary system of drainage, it becomes possible to store appreciable fractions of flood volumes. The terrain is such that reservoir capacities can be obtained at lesser cost on tributaries than on the main stem. Also, flood volumes being less, volumes of storage have a more pronounced effect upon flood flows on tributaries. The system of reservoirs installed by TVA on the Tennessee River has reduced flooding on this tributary. Levees, cut-offs and channel improvements are used to relieve local situations, but the major control is by reservoirs.

It is somewhat questionable just how far the benefits of reservoirs extend downstream but generally it is determined by the number and volumes of tributary flows and their synchronization. Additional drainage area usually means additional flow volumes and at some point downstream the reservoir storage becomes an insignificant fraction of the total flood volume. At that point the effect of a reservoir becomes insignificant.

Reservoirs on large tributaries are usually designed for multiple purposes. Power development, water supplies, etc. help to defray the cost of flood control. In this manner protection can be afforded to areas where flood control benefits alone could not be economically justified.

There are no upstream flood control benefits from reservoirs, consequently, the process of control must proceed to the very origin of flows. Detention reservoirs whose single purpose is flood control are used to regulate flows from small tributaries. As the term "detention" implies, these reservoirs temporarily store volumes of flow and expell them through drawndown tubes, installed in the dams, at a predetermined reduced rate compatible with downstream channel capacities. Downstream benefits of these reservoirs, also, are dependent upon the number, volume and synchronism of subsequent tributary flows.

Detention reservoirs are designed and constructed with a permanent pool which is below the level of the drawdown tube and is, therefore, not normally drained. The purpose of this pool is primarily to trap silt which the stream would otherwise deposit in the more expensive multiple purpose reservoirs downstream. Together with channel improvements, levees, canals, cut-offs, diversions and other means of relieving localized areas, these reservoirs afford a degree of protection to agricultural lands and installations, urban areas on the flood plains and to the multiple purpose reservoirs below.

Good land management is essential to the maximum use of the water-storage capacity in a soil. Dense vegetations protect the soil against puddling and erosion by falling rain and thereby increase the rate at which water can enter the soil. Used in rotations, they are turned under to add organic matter which increases the storage volume in the soil. Farm practices such as contour rows, strip cropping, terracing and crop rotation are designed to increase infiltration by increasing the absopption rate, increasing the storage capacity, and slowing down surface flows to permit more time for water to soak into the soil. These same practices are designed to protect and stabilize the soil against erosion.

Good land management provides five distinct benefits to flood control:

1. It increases the water-holding capacity of a soil.
2. It provides dense vegetation and thereby speeds up extraction of soil moisture to make storage space available for the next storm.
3. It increases the rate of infiltration.
4. It reduces the erosion and subsequent siltation of structures below.
5. It slows up the concentration of overland flow.

Flood reduction benefits from good land management are more pronounced on small drainage areas than they are on large drainage areas. The long durated rains which produce maximum floods from large areas are often more than sufficient to exhaust the storage capacity of the majority of soils in the watershed whereas the short duration high intensity storms, which produce the greatest peak flows from small areas, do not produce such great volumes of total rainfall. The true flood reduction benefits from good land management are not reflected by maximum floods, however. Numerous rains during the interim between major floods are absorbed or partially absorbed to greatly reduce or even eliminate the minor floods which would otherwise result. These benefits by their frequency of recurrence out-value the infrequent major-flood benefits.

Erosion control benefits and the subsequent reduction in siltation due to proper land use are not confined to any size area nor to any size or frequency of storm. Without the protections of good land management, soils are ravaged by erosion in direct proportion to the flood-producing characteristics of the storm. Without such protection the useful existence of our costly flood controls would be terminated in a very short time.

29- General Bulletin on Water Resources
30- " " " Hudson River
31 " " " Black River.

FLOODS-FLOOD CONTROL

Bulletin 28 May 1937

A COMMON-SENSE VIEW OF THE FLOOD PROBLEM

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A Common-Sense View Of The Flood Problem

In dealing with the flood problem, we recognize, of course, that we cannot prevent the rains; we cannot stop the melting of the snow; in fact, we cannot alter any of the climatic phenomena which bring about great floods. With our present knowledge, our efforts must be limited to the control of the waters after they have been precipitated upon the earth and to the alleviation of the destructive effects of excess water in the streams.

With respect to corrective measures, three lines of attack are open to us:

(1) We can PROTECT the communities in the danger zone by building dikes and embankments and similar structures and by enlarging the capacity of the river channel to such extent that the flood water will be carried past without submerging the adjacent property.

(2) We can REDUCE the flood flow by building reservoirs and retarding basins in which the excess water can be stored until the stream channel can carry it away without overflowing its banks.

(3) We can REMOVE ourselves and our property from the path of the water to places of greater safety.

In days gone by emphasis has been placed chiefly on the first two lines of action; namely, the protection of the property where it stands, and the prevention of destructive flood flow by reservoirs and retarding basins. Throughout the last century, dependence was placed almost entirely on levees and channel improvements, but, following the destructive floods in Ohio in 1913, the value of retarding basins and multiple-service reservoirs came to be more fully realized.

The third plan, however, was not entirely overlooked. Twenty-four years ago a far-sighted engineer, the late Allen Hazen, in a series of articles published in the Engineering Record pointed out that the land subject to periodic flooding should not be used for dwellings or other property which would be seriously damaged by flooding. It seems probable that, if his suggestion had been followed, most of the appalling losses of life and property, which have occurred in recent years, would have been avoided.

In his book "Flood Flow", published in 1930, Mr. Hazen again called attention to the dangers inherent in the occupation of the flood plains of the rivers. He stated that, with respect to flood hazard, the land along any river may be divided into three parts:

1. The river channel, which all agree ought not to be encroached upon.

2. The middle land, usually dry but sometimes flooded.

3. The high land above all floods.

Mr. Hazen stated that it would be theoretically possible to draw a line along the bank of a stream, above which there would be only one chance in ten that the water would rise in any given year, and to draw another and higher line, above which there would be only one chance in a hundred, and so on, for higher and less frequent floods. He stated that, if these lines could be marked across the landscape so that all could see them, much of the loss by floods would disappear, because people would then protect themselves.

The river channels in themselves are seldom occupied by private property, although they frequently are seriously obstructed, sometimes to an alarming extent, by bridge piers, railroad and highway embankments, building foundations and other structures. It is the occupation of the middle ground, subject to only infrequent flooding, which causes most of the trouble. As the years go by, the flood plain between the river bank and the high land is more and more intensively developed, not only by mills and factories, but also by dwellings and commercial and business structures. The dwellings are likely to be those occupied by the poorer classes of people. It is this vulnerable property, built in the path of the floods, which suffers most of the damage and it is in this area that the loss of life usually occurs. Unless this tendency to occupy the flood plains can be overcome, the loss of life and the damage to property by future floods will continue to grow larger.

As Hazen pointed out, the early settlers were apt to be cautious and they usually built their homes upon the higher ground, but as communities grew in size and commerce increased, post roads and railroads were built along the river banks. Knowledge of flood conditions was

often inadequate, memories were short, and new settlers unfamiliar with local flood experiences were tempted to buy and develop low-lying land for manufacturing, warehousing, home building and other purposes. In particular those with little capital sought the cheaper lands close to the rivers, and often unknowingly assumed the risk of destruction by flooding. As the original settlements increased in size and as commerce and manufacturing developed, they encroached farther and farther upon the stream. In some cases, even the shallow parts of the stream bed have been filled in and built upon. Under such conditions destruction is inevitable when a great flood occurs.

It is not to be inferred from the foregoing statements that the whole flood plain of a river should be reserved exclusively as a floodway. Many of these areas are of such value that they must be used, and the property thereon must be protected by channel enlargements, dikes, levees and reservoirs. In some cases, parts of the flood plain can be reclaimed by filling to higher and safer levels, and some businesses may be so conducted that damage by flooding will be limited, and it will thus pay to take the risks of an otherwise advantageous location.

But the point to be emphasized is that the increasing use of land in the middle, or flood zone for business and residential purposes is chiefly responsible for the great increase in damage from floods.

The occupation of this middle zone has an indirect influence in increasing the height of floods resulting from a given flood discharge. Highways and railroads may be built across the flood plains with bridge openings large enough for only moderate floods. Warehouses, factories, and other structures on the low land all add resistance to the passing water and increase the flood stage far upstream. One such structure may have little influence, but, when the number is increased until the whole flood plain is occupied, the aggregate effect is to vastly increase the height of the water and the resulting damage.

To meet this situation, millions of dollars of public funds have been expended for the building of levees, protecting walls, retarding basins and river regulating reservoirs. Unless such improvements are adequate for protection against the highest floods, because of their very existence they may create a false sense of security which may lead to still further construction upon the middle land or flood plain.

Within recent years agricultural experts and foresters have been giving increased attention to the problem of soil erosion. They claim that by restoring the forest cover of cut-over upland areas, particularly those which have been abandoned for agriculture, and by such improved agricultural methods as contour plowing, strip cropping, and proper crop rotation the infiltration of water into the soil can be greatly increased, and the rapid run-off and resulting erosion from rain and melting snow can be reduced. There is evidence that much good can be accomplished by these practices, particularly from the viewpoint of soil erosion. This state in cooperation with the federal government has for a number of years been encouraging such sound agricultural practices and has also been a leader in reforestation work. This work should be encouraged. It is well known that forests are effective in preventing erosion, particularly sheet erosion, and also well known that the layer of humus and forest litter on the ground acts as a sponge in absorbing precipitation and retarding runoff in the early stages of a rainstorm. But, when a sponge is once saturated, additional water poured upon it runs off as rapidly as it would off a tin roof. When great quantities of rain fall upon saturated ground, however spongy, it is bound to run off rapidly in spite of growing forests and sound agricultural practices. We must face the problem of the unusual flood, such as inevitably results from a continued rain storm of 8 or 10 or 12 inches precipitation.

Since it is seldom economically feasible to offer complete protection from flood damage, even by a costly system of dikes, levees, reservoirs and protective works, or even by extensive reforestation and the best agricultural practices, it would appear to be unwise to rely entirely on our efforts to keep the rivers out of the cities, villages and towns. It would seem to be only common sense to go back to first principles and see what can be done toward keeping the communities out of the way of the rivers. Such a policy consists simply of refraining from building certain types of improvements, particularly dwellings, on land that is sure to be flooded from time to time. It will not be practicable nor necessary to do this in all instances but along many rivers and streams there are, on land high enough to be out of danger, ample sites for all the business that needs to be accommodated and for the homes of all the people who now live in the danger zone.

The flood plains thus freed from dangerous obstruc-

tions need not become waste land; they can be used for many desirable purposes, such as river front parks, automobile parking areas, railroad yards and for certain kinds of business and manufacturing. Along the rivers that flow through cities much of the low land might well be used for park purposes. Parks can be built and maintained so as not to interfere with the occasional use of the full flood channel. The parks will be damaged sometimes by floods, but the damage will be relatively small and easily repaired. Think what an improvement it would be if those portions of a city or village now built in part in the flood plain of a river could be moved back to higher ground with the river bank and the lower part of the occasionally flooded area laid out as a public park with ample roads and drives. Arrangements of this general character are found in some European cities and less frequently in America.

In this connection the offer of the Reconstruction Finance Corporation of the federal government to help finance the movement of individuals, industries and even whole communities from frequently-flooded bottom lands to perpetually safe highlands is welcome news. It points to a more realistic view of the flood problem than has prevailed heretofore. There is little excuse for the water front location of thousands of properties damaged in the recent floods.

The Engineering News-Record in an editorial in its issue of March 11, 1937 wisely says,

> "Traveling down the Ohio during the recent flood one could notice scores of farm homes completely inundated though standing only a stone's throw from high ground. Villages were flooded, while a few hundred yards away dry land rose above the muddy waters. Is it sound economics to let such property be damaged year after year, to rescue and take care of the occupants, to spend millions for their "local protection," when a slight shift of location would assure safety?
>
> "Is it right that the country as a whole should pay for local protection of such vulnerable spots as Wheeling Island, where 10,000 people insist on occupying a low-lying island that is hardly more thar awash at low water? Is it right to perpetuate decrepit slum districts in the flood zones of the larger river-bank cities, peopled by masses that

become refugees and relief cases in every high water? Portsmouth has answered this question by declaring its intention to convert its low-lying sections into a park.

"The federal government has never seen fit to establish floodflow boundaries for its rivers, though in the interest of navigation it has long assumed the right to mark low-water channels. Pierhead and bulkhead lines are laid out in every harbor and navigation clearances are set upon which no encroachment may be made. Yet people and industries have been permitted to occupy normal flood channels, and flowageways have been restricted by filling in and by commercial development without federal protest.

"It may not be possible at this late date to restore the flood ways to the rivers completely. Occupation and development of the flood plains have proceeded so far that we are now forced to spend huge sums to control floods. Plans for reservoirs and floodwalls are commendable; their cost, staggering though it may be, is less than the loss caused by one big flood. Yet in planning flood relief let us remember that the river has rights, and these rights must be respected."

There is much to be said in favor of such a course. For a generation or more the old inadequate, often insanitary, dwellings of our urban settlements on the flood plains have been tending to become seriously blighted districts or slums. Public officials and civic-minded citizens have been praying for the day when they could wipe out those unsatisfactory areas and rehouse the people living therein on safer upland sites where more spacious and more wholesome living conditions could be provided to their inhabitants. City planners have dreamed of the opportunity to create these more wholesome conditions, and at the same time to solve many of the vexing problems that are inherent in the narrow congested streets that characterize those old areas, relics of a bygone day.

In considering the removal of residential property from the flood zone, a direct comparison of the cost of a proposed flood-control project with the value of the property to be abandoned does not tell the whole story. Many flood-control improvements furnish partial, rather than complete, protection and extreme floods may still cause damage, even after control works have been built. If retarding basins are used, they are apt to pre-empt the best

sites on the watershed which might otherwise be utilized for multiple-service reservoirs, when need arises, for water power, water supply, river regulation or recreation.

On the other hand, if a move from the flood plain to a safe elevation is made, complete protection against all possible floods can be secured, once and for all, as easily as partial protection. Such a move need not be made all at once, but over a period of years as the structures become depreciated and obsolete. Some of the buildings in these waterfront districts are no more valuable than those which other cities are tearing down and rebuilding as part of their slum clearance schemes. Many of these buildings will be abandoned for other reasons than floods within the next 20 to 30 years, and, if at such times they are replaced on a new and safer site, the cost of the change will not be great.

The new development on higher ground, through modern town planning for twentieth century conditions, may so far exceed the efficiency of some of these districts as to justify most of the cost of the change, leaving the amount fairly chargeable to flood avoidance considerably less than the cost of protective works.

In the opinion of the Division of State Planning the time has come for the formation of a definite policy toward flood control by the state and its municipalities. The Division, therefore, offers the following, in the hope that it may serve as a guide to the formulation of definite municipal plans.

A PROGRAM OF PRACTICAL STEPS FOR THE ULTIMATE EVACUATION OF THE FLOOD PLAINS

It is suggested:

1. That the appropriate officer or governing body in each community so situated as to be subject to serious flood hazard determine, in so far as possible, the area subject to flood damage and clearly inform the citizens of the community of the limits of such flood district.

2. That each river community, by action of its governing body, amend its zoning and building codes in such manner as to prevent the construction of new dwellings in the potential flood district, and to limit commercial and industrial structures in accordance with the hazard involved, in much the same manner as fire zones are now established. That each municipality under the police power,

be authorized to require the gradual removal or modification of obstructions in stream channels and the removal of such hazardous structures as oil tanks which may break loose and add to the flood danger, the further danger of fire.

3. If it has not already done so, that the governing body of each river community create a planning board and appropriate sufficient funds for the preparation of a comprehensive city, village, or town plan, including a program for the development of suitable building sites on higher, safer land, with necessary public facilities, such as streets, sewers, water mains and schools, for the people now occupying land within the flood zone, to the end that as such facilities are provided there may be a gradual voluntary removal of persons and vulnerable properties out of the danger zone.

4. That the governing body of each such river community establish in some appropriate municipal office a committee or agency to cooperate with the residents of the flood zone and with the Federal Reconstruction Finance Corporation in financing the movement of individuals and industries from such flood districts to higher and safer land.

5. That such planning board also work out a plan and program for the ultimate public acquisition of the land in such designated flood district for waterfront parks or other suitable public uses or alternatively to develop a plan by which such land may remain in private ownership for such uses as may not be incompatible with adequate flood protection.

6. Such part of the cost of flood control works, such as retarding basins, regulating reservoirs, dikes, levees, walls, etc. as may be allocated to the local community should be borne primarily by the property protected by such improvements rather than by the community as a whole. Our present procedure under the river regulating district law permits the apportionment of the cost upon the properties benefited, but in practice the assessments against a municipality are made a city or village charge and so fall upon the prudent home owner, who has built upon the hill, as well as upon the owner of the property subject to damage.

In effect we now subsidize the continued occupancy of the flood plain by charging the cost of protection against all the people, through general taxes.

Such a program will unquestionably require some further permissive enabling legislation. For the development of such a legislative program the Division of State Planning offers its assistance to the municipalities of the state.
Such a program, if adopted, would-

1. Define the areas of danger.

2. By zoning, limit development in the more hazardous areas.

3. Prepare alternative safer and more adequately equipped areas to which the occupants may move.

4. Provide a local agency to assist in such removal.

5. Provide for the ultimate public acquisition of such land and for its use in ways which will not interfere with the relatively free passage of flood waters.

6. Require that the local share of the cost of such flood protection works as may be constructed shall be borne by the property in the areas protected rather than by general levy on the taxpayers of the whole municipality, or the state or nation.

If the cities, towns, and villages of the Empire State cooperate in the development of such a program, the Division of State Planning believes that New York will point the way to a common-sense and realistic solution of a problem that otherwise bids fair to become a national menace.

Part V

6. Groundwater Provinces in the United States

The United States may be divided into a number of broad groundwater provinces, just as it may be divided into a number of broad soil conservation problem areas. To some extent, however, these groundwater provinces overlap because groundwater is found in different formations vertically at the same place. For example, in the glaciated areas there may be groundwater supplies in the glacial material and also ~~groundwater~~ in the underlying bed rock material.

Figure 173 shows the distribution of the glacial groundwater province. The area shown in black is covered by glacial drift left by the melting of the continental ice sheets. Local glacial deposits are also found in the mountainous regions of the West, but these are at relatively high elevations and are of no significance from the groundwater standpoint.

The great bulk of the glacial material is till, which consists of unassorted sediment ranging in size from boulders down to finely ground rock particles of the ~~fineness~~ texture of silt and clay. The average permiability of the till is low. In addition to the till, there are other better sorted glacial deposits, some of which are highly pervious and form excellent groundwater acqifers.

The glacial streams which issued from the edge of the ice sheet laid down sorted alluvial fans which often coalesce to form a distinct stratum. These deposits are known as glacial outwash and glacial aprons and generally consist predominantly of sand and gravel.

Deposits of sand and gravel laid down by streams running under the glacier may be found in the form of low hills (Kames) or long sinuous ridges (Eskers) ~~known as Kames and Eskers~~. There are also stratified deposits laid down in glacial lakes which are generally rather fine textured and impermiable. In part the glacial materials have been redeposited by wind in the form of loess.

GROUNDWATER GENERAL

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The unassorted till usually furnishes only small supplies of water, but these may be sufficient for domestic purposes. If the till contains any pervious members, these are usually concentrated either at the top of bottom of the till sheet. In some cases, there are several such layers where till sheets have been laid down by successive advances of the ice. The contacts between deposits of each glacial period are usually water-bearing and the contact horizon may be marked by springs.

The gravel and sand deposited by glacial streams in old previously cut valleys are later covered by thick sheets of till in many places such as in Ohio. These old buried valley gravels now furnish large water supplies, ~~off Ohio maps.~~ Also glacial outwash aprons and valley trains beyond the terminal moraines of the ice sheets in New England and elsewhere, form valuable sources of groundwater supply.

~~Figure 17A shows the great sheet of~~ Great Plains Tertiary alluvium Tertiary alluvium which underlies large part of the Great Plains and parts of the central Rocky Mountain areas. ~~This material~~ was ~~all~~ eroded from the ancestrial Rocky Mountains and transported by overloaded streams and deposited in Piedmont areas. These deposits of gravel, sand and clay variously assorted and stratified are nowhere more than a few hundred feet thick. In most areas they are porous enough to furnish at least some water and they contain abundent, irregularly distributed lenses and stringers of gravel and sand that yield large quantities of good water to many wells. They constitute one of the most valuable underground water supplies in the United States, ranking among the first in quantity of water, quality of water, and number of wells supplied in extensive productive areas. They are one of the principal assests of the semi-arid Great Plains. They give rise to only a few flowing wells but the pumping lifts are generally not great.

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There are also alluvial deposits of later age in the principal valleys traversing the Great Plains, including particularly the Arkansas and Platte Rivers. This valley alluvium is continuous for hundreds of miles east of the Rocky Mountains and in some places expands to considerable width. In part of the Platte River Valley the belt of alluvium ranges from 5 to 20 miles in width and contains large quantities of good water which it yields very freely to wells. In most of the areas ~~shown on this map~~, it is believed that there are possibilities for conservation practices to aid groundwater recharge. The stratification is so variable that a great deal of study will be required.

~~Figure 175 shows the areas of~~ Recent valley fill deposits southwestern United States ~~underlain by recent valley fill deposits~~. The chief water bearers of these deposits are the alluvial cones and fans. Their structure and permiability depends upon the bed rock formations of the adjacent mountains from which they were derived. Groundwater of the Great Basin region is largely in alluvial deposits of this type, as are the principal groundwater sources in the Great Valley of California and in the inter-mountain valleys of the Pacific coast ranges.

~~Figure 176 shows areas of~~ western United States ~~overlain by~~ Tertiary or Quaternary volcanic rocks. These lava formations control the occurrence of groundwater and delineate an important groundwater province. The largest continuous area of lava is that constituting the Columbia Plateau and its extentions covering portions of Idaho, Washington, Oregon and California. A second large area, the Gila River lava field covers a portion of the Colorado Plateau in eastern Arizona and western New Mexico. These lavas are for the most part rather permiable, being full of small cavities and joint systems.

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these areas is held in fractures in the rock, in the deep but irregular mantle of weathered material including the soil, and local accumulations of alluvium in the valleys. In general, groundwater is widely distributed but not present in very large amounts for pumping or commercial uses.

Figure 178 show the areas of Paleozoic sedimentary rocks. The entire region where Paleozoic rocks occur near the surface contains rather unsatisfactory groundwater supplies. Wells more than a few hundred feet deep are apt to encounter saline water. Good water is generally encountered within 200 to 300 feet of the surface, except in Kansas, Oklahoma and Texas where the saline water may extend up to the water table. The best supplies in this area are in alluvial deposits of the stream courses or in the overlying glacial deposits. Several water-bearing sandstone formations do occur, however, the most important of which are the Potsdam sandstone of Cambrian age, the Saint Peter sandstone of Ordivician age and the Pottsville sandstone at the base of the Pennsylvanian. Limestone and dolomite beds also carry water in solutional openings, but only where conditions have been favorable for the development of such openings. Flowing wells are obtained where structural and topographic conditions are favorable.

Figure 179 shows areas of the northern Great Plains and adjacent Rocky Mountain and Colorado Plateau provinces in which Rocks of Upper Cretacious age occur near the surface. These are chiefly thick shale formations with some interstratified sandstones. Where these formations are not covered with alluvial material there are only scanty groundwater supplies near the surface, because the greater portion of this series consists of shale. The one great acquifer is the Dakota Sandstone which underlies most of the North Dakota, South Dakota, Nebraska and also the western portions of Kansas, Iowa and Minnesota. The strucuture of this formation is that of an irregular synclinal basin with dips so flat that the water-bearing beds can be reached over an area of

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thousands of square miles. This sandstone is generally not more than 100 feet thick and is overlain by predominantly shaly and dense, plastic, impervious shales that will yield no water. These shales may range up to several thousand feet thick and are very effective in confing the copious supplies of the Dakota sandstone under artesian pressure. There are a few locally-good water-bearing beds at various horizons above the Dakota.

~~Figure 180 shows areas of~~ Atlantic and Gulf Coastal Plains ~~in which~~ The Cretaceous and Tertiary formations ~~occur near the surface.~~ of this province ~~These formations~~ are non-indurated and were laid down when the ocean transgressed upon the eastern and southern shores of the North American Continent. They are covered locally by terrace deposits and by old stream gravels. The catchment area of each pervious marine formation is the outcrop area, and the depth to the acquifers is shown in geologic cross sections at many places. The acquifers are porous sandstone and pervious limestone formations. Artisian water is commonly encountered down the dip of the sandstone aquifers. The quality of groundwater in some of the aquifers is ruined by formational saline contamination, especially in Texas.

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SEVERE FLOODS AT NEW BRAUNFELS, TEXAS MAY 1972

by

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SUMMARY:

This report describes in detail the flood-producing storm of May 11-12, 1972, in the New Braunfels, Texas, area. Sixteen inches of rain fell in a 4-hour period. Fifteen lives were lost to the rampaging floodwaters that inundated 400 homes and caused approximately $5,700,000 in damages.

American Society of Agricultural Engineers

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SEVERE FLOODS AT NEW BRAUNFELS, TEXAS
May 1972

Description of Area

New Braunfels, the county seat of Comal County, is referred to as the "Gateway to Texas' Picturesque Hill Country." It lies deep in the heart of Texas where undulating plains meet the Balcones Escarpment and where the deep Comal River flows into the swift Guadalupe River. Nature has richly endowed the community with abundant water and tropical foliage which contribute to a lush setting that long ago earned the title "Oasis of Texas." The city is noted for its historical sites and buildings and the city-owned, 150-acre Landa Park which provides the largest springfed swimming pool in the southwest, a filtered olympic pool, an 18-hole golf course, and botanic gardens. Also, summer homes and river resorts provide vacation facilities that have become famous.

A scenic drive follows the Guadalupe River for 17 miles upstream from New Braunfels to Canyon Lake, which retains 366,400 acre-feet of water in its conservation pool. Eighty miles of wooded shore line surround the beautiful blue waters of the lake. The lake provides flood protection to New Braunfels.

Large springs located in New Braunfels form the 2-1/2 mile long Comal River, which flows into the Guadalupe River. The Comal is the shortest river in Texas and the shortest in the United States carrying an equivalent amount of water. The average flow from the springs is 303 cfs.

Both the Comal River and the Guadalupe River, with their high discharges of clear water and tree-lined banks, provide beautiful settings for homes and recreation facilities. The threat of floods has not prevented development along the river banks.

The town is a growing community of about 18,000 inhabitants. It boasts good fellowship in the German manner and the informality of a "small town" atmosphere.

Physical Factors Affecting Floods In The Area

New Braunfels is located in south-central Texas along the Balcones Escarpment, which separates the Great Plains and Coastal Plain physiographical provinces. To the south and east of the escarpment, the extensive lowland of the Coastal Plain province rises from sea level to an average of about 700 feet at the sudden uplift of the Balcones Escarpment. Actually a broken line of hills, the Balcones Escarpment marks the Balcones fault zone. From a point near Del Rio on the Rio Grande, the fault zone and its accompanying scarp run eastward to a point just north of San Antonio, and then swing northeast, crossing the Colorado River just above Austin. Although it is less well defined northeast of the Colorado River, the escarpment runs north all the way to the Red River.

The Balcones fault zone consists of a series of more or less parallel faults. Most are of the normal or extension type with the downthrow to the south or east. They range in length from a few hundred feet to about 50 miles.

Displacement is greatest generally near the middle of the fault trace, and the maximum displacement of any single fault is about 700 feet. At New Braunfels, the combined displacement of all faults is about 1,500 feet.

In general, precipitation is heaviest along the escarpment that faces the Gulf of Mexico. Presumably, this results from the moisture-laden air being lifted as it moves northward from the Gulf, and from thunderstorms being initiated where moist air is forced to rise. The most prominent instance in Texas of heavy rainfall related to topography occurs in the vicinity of the Balcones Escarpment. In parts of the area along the escarpment, the mean annual rainfall changes at the rate of 1 inch in 4 miles.

Some of the most notable rainstorms on the North American continent have occurred along the Balcones Escarpment. For example, 38.2 inches fell in 24 hours at Thrall on September 9-10, 1921. During this storm, an official measurement of 19.65 inches in 12 hours was recorded at Taylor, and an unofficial measurement of 32 inches in 12 hours was made 2 miles north of Thrall. The greatest of all continental United States rainstorms, this storm resulted from a combination of several factors, the most important of which were:

1. An invasion of southern Texas by an unusually unstable air mass associated with a dissipating hurricane

2. Continuous lifting of this unstable air mass by the Balcones Escarpment.

On Little River at Cameron, Texas, with a drainage area of 7,088 square miles, the storm produced 647,000 cfs peak discharge. This peak discharge is the second highest recorded at a stream gauge in Texas.

Also, along the Balcones Escarpment, a rainstorm of June 10-15, 1935, was centered northwest of Uvalde. Rainfall recorded at the center of the storm was 17.6 inches. Approximately 12.5 inches of this fell in a 10-hour period. Peak discharges of 580,000 cfs from a 402-square-mile drainage area on the west Nueces River near Brackettville, Texas, and 616,000 cfs from a 1,930-square-mile drainage area on the Nueces River at Uvalde, Texas, resulted from the storm. These are the third and fourth largest flood discharges ever recorded in Texas.

Another classic rainstorm occurred along the Balcones Escarpment near D'Hanis between San Antonio and Uvalde on May 31, 1935. At the center of the storm, 22 inches of rain fell in a 2-3/4 hour period.

Even the beautiful Pedernales River has not escaped the high intensity rainstorms and devastating floods that occur along the Balcones Escarpment. On September 9-11, 1952, a rainstorm occurred on the river basin with 28.8 inches of rainfall reported at the center. The resulting flood peak was 441,000 cfs on a drainage area of 947 square miles, at Johnson City. The flood transported the largest recorded sediment load per square mile of watershed area in Texas. This sediment load measured 8.8 acre-feet per square mile of watershed area in a watershed area of 947 square miles.

The escarpment along the Balcones fault zone tends doubtless to increase the rainfall in its vicinity to some extent because it forces the warm moist air from the Gulf to rise, then to expand and cool, thus inducing heavy rainfall. Upstream from the escarpment, the area is deeply dissected and rapidly drained.

The steepness of the slopes, the shallowness and rocky character of the soil, and the narrow flood plains of the stream channels all contribute to the severe floods that occur in the area.

Rainfall

A flood-producing storm occurred in the New Braunfels area on May 11-12, 1972. The intense rain cell that produced severe flooding formed to the southwest of New Braunfels and moved in a northeasterly direction. See Figures 1 and 2 for radar location of rain cells.

Rainfall reports collected from local residents were used to develop the isohyetal map (Figure 3). About 100 people were contacted during the "bucket survey" for rainfall amounts. The reports were based on standard gauges, buckets, barrels, cans, milk cans, and other containers that were available. Also, these people were interviewed for an approximation of when the rain began, how long it lasted, and the time the highest intensity rainfall occurred.

Three automatic recording-type rain gauges were located at and near Canyon Dam Reservoir. Also, one recording-type rain gauge was located on Trough Creek at State Highway 46. (Location shown on isohyetal map, Figure 3.)

The recording rain gauge on Trough Creek, operated jointly by the U. S. Geological Survey and the Texas Highway Department, indicated that by 8:00 p.m. on May 11, 1972, it had collected 0.6 inch; by 8:10 p.m., 2.9 inches; and by 8:20 p.m., 3.6 inches of rain had fallen, at which time the gauge began to siphon and no further rainfall was recorded. This is 2.3 inches in 10 minutes and 3.0 inches in 20 minutes. The three recording rain gauges at and near Canyon Dam are operated by the Corps of Engineers and National Weather Bureau. These gauges were on the fringes of intense rainfall, but reported a good rainfall distribution for the entire storm duration. Figure 4 shows a unit distribution of the storm rainfall taken from the Canyon Dam No. 1 recording gauge.

Table 1 shows a depth-area listing of the various weighted rainfalls for the entire storm area and a plotting is shown on Figure 5.

The storm, which was accompanied by a violent electrical storm, started at about 8:00 p.m., May 11, 1972, and lasted until about midnight.

Several of the people contacted during the survey reported a very high intensity rain; one person observed 12 inches of rain between 8:40 p.m. and 9:40 p.m. on May 11, 1972.

The center of the storm had about 16 inches of rainfall in a 4-hour period. From all reports, the storm period lasted for about 4 hours.

The 16 inches of maximum point rainfall, recorded in 4 hours, is 2.5 times that of the 4-hour, 100-year point rainfall of 6.4 inches, based on U. S. Weather Bureau Technical Paper No. 40. No attempt has been made to place a frequency on a storm of this magnitude.

The runoff-producing storm was preceded by rain over the entire watershed during the 1-week period prior to the storm. The prior rainfall amounts averaged about 7 inches.

Soils in the storm area are very shallow to deep and slowly to moderately permeable. There are large areas of exposed rock. The principal land use is rangeland. The hydrologic cover conditions range from poor to good, but the majority is fair to good.

Runoff

Flood discharges were recorded by the Geological Survey at three stream gauges in the storm area. These were Guadalupe River above Comal River, at New Braunfels, Texas; Comal River at New Braunfels, Texas; and Trough Creek near New Braunfels, Texas. Also, peak discharges were determined at miscellaneous sites on Blieders Creek near New Braunfels, Dry Comal Creek at New Braunfels, and Guadalupe River near New Braunfels.

The stream gauge on the Guadalupe River at New Braunfels was installed in 1928. The drainage area at the gauge is 1,518 square miles, but flow from 1,432 square miles has been largely regulated by Canyon Lake since June 1964. The 1972 flood was the result of runoff from 86 square miles. The flood peaked at 92,600 cfs and occurred on May 12 at 0030. The flood crest at New Braunfels rose 12.5 feet in 30 minutes and 28 feet in 2 hours. Figure 6 shows flood elevation with respect to time at the stream gauge. The maximum discharge of 101,000 cfs previously experienced at the gauge occurred in 1935 before Canyon Lake was built.

The stream gauge on the Comal River records runoff from 130 square miles. The period of record began in 1882. Flow of the river is primarily from Comal Springs, except during periods of local rain. The springs emerge from the Edwards and associated limestones in the Balcones fault zone. They have the largest flow of any Texas springs, averaging 303 cfs. This gauge was inundated by flood waters and ceased to function during periods of the flood. The plant manager of the Lower Colorado River Authority (LCRA) electrical power plant recorded water surface elevations at regular time intervals. These were used by the Geological Survey to prepare the flood hydrograph at the gauge. The hydrograph shows that two flood peaks occurred. The first, of 60,800 cfs at 2345 on May 11, was largely from Blieders Creek. The second, of 55,800 cfs at 0530 on May 12, was caused by Dry Comal Creek. Figure 6A shows the water surface elevation with respect to time. The flood crest rose 7-1/2 feet in 15 minutes and more than 30 feet in 1-3/4 hours.

Approximately 4.4 inches of surface runoff from the 130-square-mile drainage area resulted from the 8.05 inches of weighted rainfall. The previously recorded maximum discharge was 35,000 cfs in September 1952.

The stream gauge on Trough Creek is a partial record station in the Texas Highway Program. The drainage area is .48 square mile and is located between the 10- and 11-inch isohyetal lines. The maximum discharge of 2,510 cfs is 5,230 cfs per square mile. This unit discharge is a new record high for Texas.

The miscellaneous site measurement on Blieders Creek was made at State Highway 46 in the north edge of New Braunfels. The 15-square-mile drainage area produced a peak discharge of 48,400 cfs.

The miscellaneous site measurement on Dry Comal Creek was made at the MOPAC Railway Bridge. The drainage area is 112 square miles and the peak discharge was 56,400 cfs. From local flood information, the 1952 flow stage was about

5 feet lower than the 1972 flood.

The miscellaneous site measurement on the Guadalupe River was made at State Highway 46. The site is about 1 mile upstream from the gauging station. The maximum discharge was 100,000 cfs.

Flooding

The inhabitants of New Braunfels have recognized the constant threat of floods on the Guadalupe and Comal Rivers. Canyon Lake, controlling flood runoff from 1,432 square miles on the Guadalupe River above New Braunfels, was built by the Corps of Engineers. The dam was completed in 1964. It provides a high level of protection to New Braunfels for most floods originating on the Guadalupe River. The 1972 flood had its origin downstream from the Canyon Dam.

In 1968, a work plan for watershed protection and flood prevention for the Comal River Watershed was prepared by the Comal-Hays-Guadalupe Soil and Water Conservation District; Comal County Commissioners Court; the City of New Braunfels, Texas; and the Edwards Underground Water District. The work plan included installation of three floodwater retarding structures controlling flood runoff from 60.23 square miles. Prior to work plan development, Comal County constructed two floodwater retarding structures with a combined drainage area of 14.35 square miles. Thus, when the planned structures are installed, flood runoff from 74.58 square miles (58 percent) of the Comal River Watershed will be controlled (Figure 7). Two additional sites for floodwater retarding structures, Rock and Solms sites, were investigated during work plan development (Figure 7).

A digital computer model of the storm on the Comal River Watershed was made using the Soil Conservation Service Project Formulation Hydrology Program. Table 2 shows the effects of floodwater retarding structures at each of the sites.

Flood profiles showing present and with-project conditions for Blieders Creek, Dry Comal Creek, and Comal River are shown on Figures 8, 9, and 10, respectively. Reductions to floodwaters and depths of flooding are shown on these profiles with the planned floodwater retarding structures.

Figure 11 shows the areas inundated during the May 11-12, 1972, storm and the areas that would have been inundated with project conditions within the Comal River watershed.

Figures 9 and 10 show what effect two additional sites not planned (see Figure 7) would have on flood depths along Dry Comal Creek and Comal River.

Figure 12 shows the area inundated during the May 11-12, 1972, storm along the Guadalupe River.

Damages

The most extensive urban damages occurred along the Guadalupe River, Blieders Creek, and Comal River. Severe urban damages also occurred along Dry Comal Creek.

There were 15 lives lost from this flood within the Comal and Guadalupe Rivers Watershed. Forty-five homes were completely destroyed or damaged beyond repair by the rampaging floodwaters. About 400 homes were inundated by floodwaters ranging in depths from a few inches to more than 10 feet. About 20 business firms and resorts were damaged severely by the flood. One resort facility was completely destroyed. Other damage was to the city park and its facilities, to city streets and bridges; water, sewer, and gas lines; water supply and pumps, maintenance buildings, and equipment. Homes that were inundated had damage to fences, household goods, furniture, and personal property such as automobiles and commercial vehicles.

Urban damages along Dry Comal Creek, Blieders Creek, and Comal River total approximately $3,300,000 from this flood. With installation of the project, this damage would have been reduced to $180,000. Had two more additional sites, Rock and Solms sites, been installed this would have reduced the damages to $133,000.

Although installation of the planned structural measures would not have eliminated 100 percent of the damages, there probably would have been no loss of human life within the Comal River watershed, and many personal belongings could have been saved. In the lower reaches of Comal River, along Guada-Coma Street (Figure 9) flooding would have been reduced but not eliminated.

Urban damages along the Guadalupe River in New Braunfels total about $2,400,000 from this flood. The watershed protection and flood prevention project on the Comal River Watershed would have little effect on these damages. Monetary damages in New Braunfels total about $5,700,000 from this flood.

Extensive damages to growing crops and rural developments have not been evaluated. Also, flood damages occurred to urban areas along the Guadalupe River for many miles downstream.

TABLE 1

May 11-12, 1972, New Braunfels Storm

Total Storm Area

Weighted Rainfalls for Various Areas

Weighted Rainfall (Inches)	Area (Square Miles)	Ratio Areal to Point Rainfall
16.5	0	1.0
16.25	.08	.985
15.53	2.38	.945
14.87	6.54	.90
14.15	13.84	.860
13.14	35.66	.798
12.20	83.28	.740
11.64	124.00	.707
11.23	153.96	.683
10.89	175.84	.660
10.45	201.76	.635
9.76	244.84	.593
8.96	301.32	.545
8.28	355.60	.503

TABLE 2

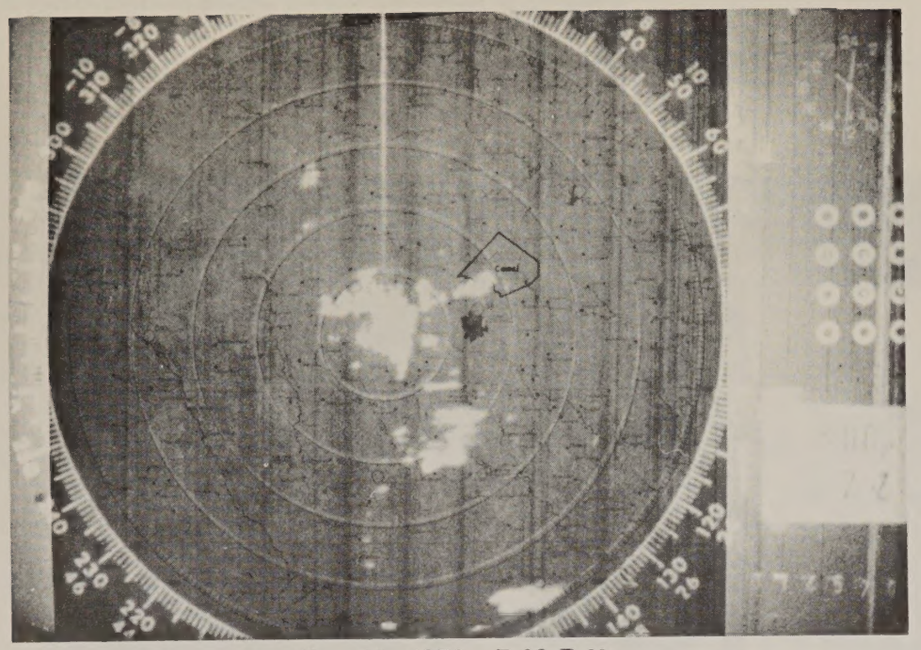
Effects of May 11-12, 1972, Storm at Various Floodwater Retarding Structure Sites

Structure Number or Name	Emergency Spillway Width (feet)	Emergency Spillway Type	Present Conditions (as of May 11-12, 1972 Storm) Peak Discharge (cfs)	Present Conditions (as of May 11-12, 1972 Storm) Emergency Spillway Depth of Flow (feet)	With Project Conditions Peak Discharge (cfs)	With Project Conditions Emergency Spillway Depth of Flow (feet)	Project Conditions Plus Two Sites Peak Discharge (cfs)	Project Conditions Plus Two Sites Emergency Spillway Depth of Flow (feet)
1	400	Rock	19,620	None	900 3/	None	900	None
2	325	Rock	41,230	None	4,000	3.5	4,000	3.5
3	600	Rock	41,100	None	6,100	2.8	6,100	2.8
4 1/	380	Rock	125	None	125 3/	None	125	None
5 1/	150	Veg.	1,580	2.7	1,580	2.7	1,580	2.7
Rock Site 2/	375	Rock	19,820	None	19,820	None	5,510	0.8
Solms Site 2/	300	Veg.	1,970	None	1,970	None	80	None

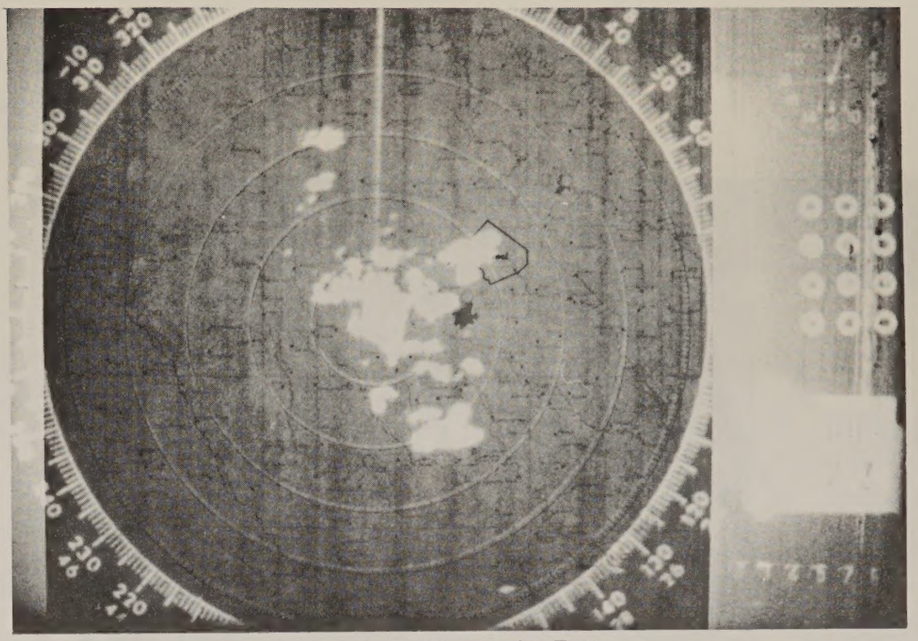
1/ Structure completed prior to storm of May 11-12, 1972

2/ Not considered as part of final project formulation

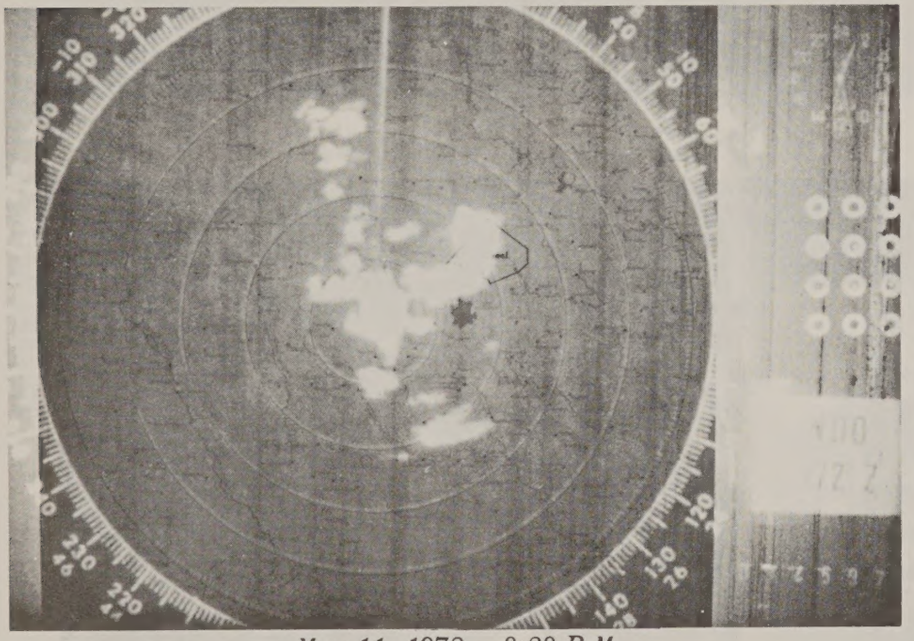
3/ Principal spillway flow only



May 11, 1972 7:30 P.M.



May 11, 1972 8:05 P.M.



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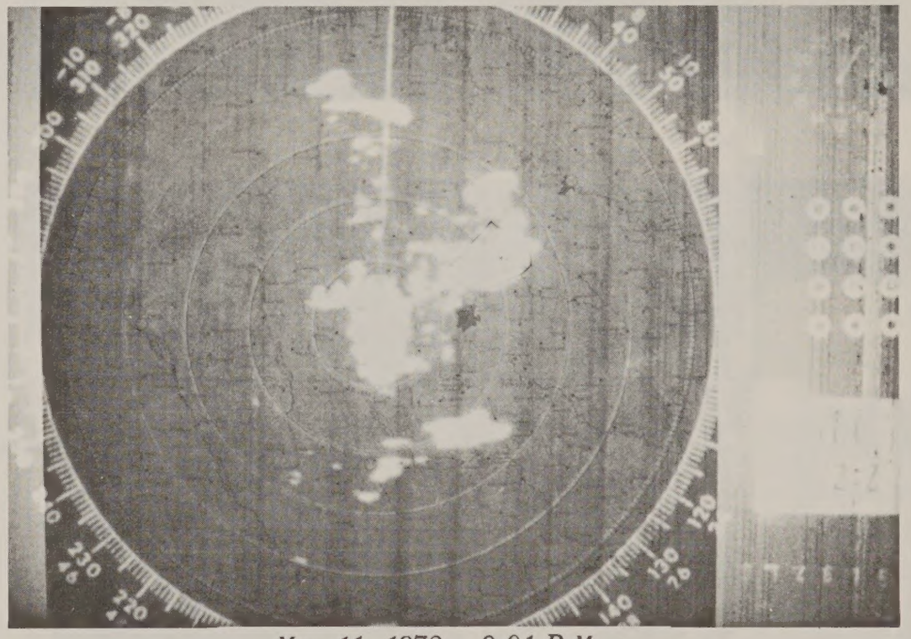
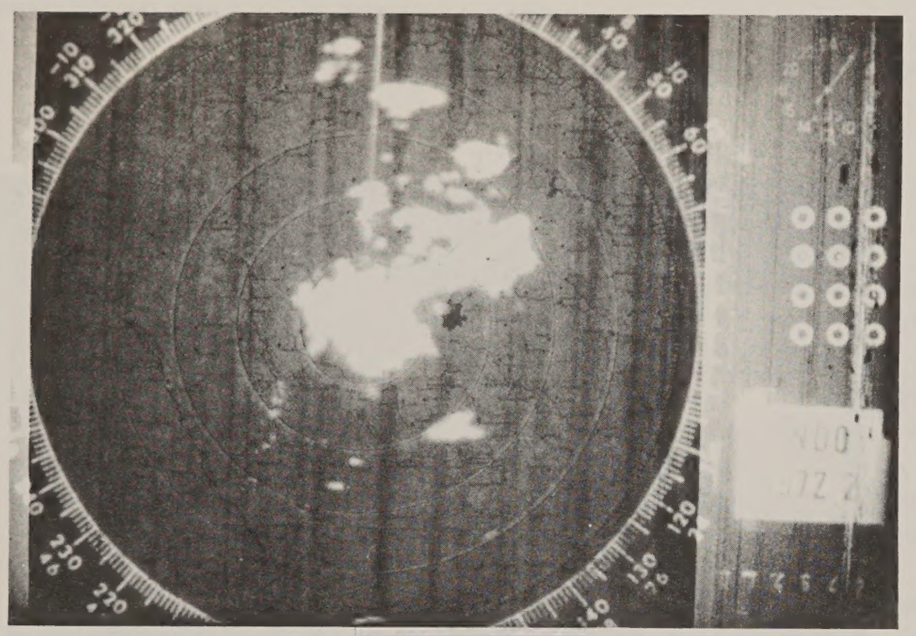


May 11, 1972 9:01 P.M.

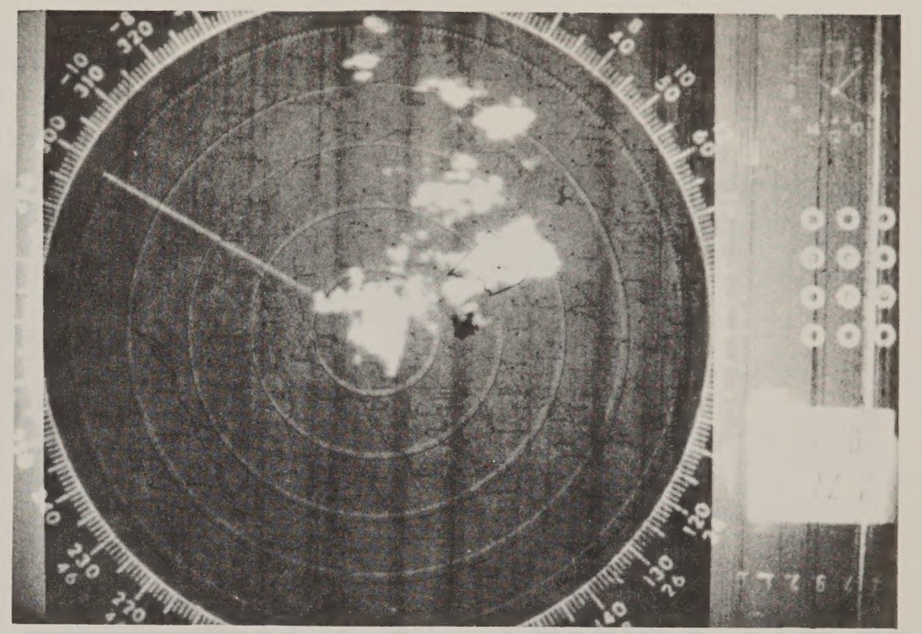
Figure 1

Hondo, Texas, Radar Pictures of Intense Rain Cells, May 11–12, 1972 New Braunfels Storm

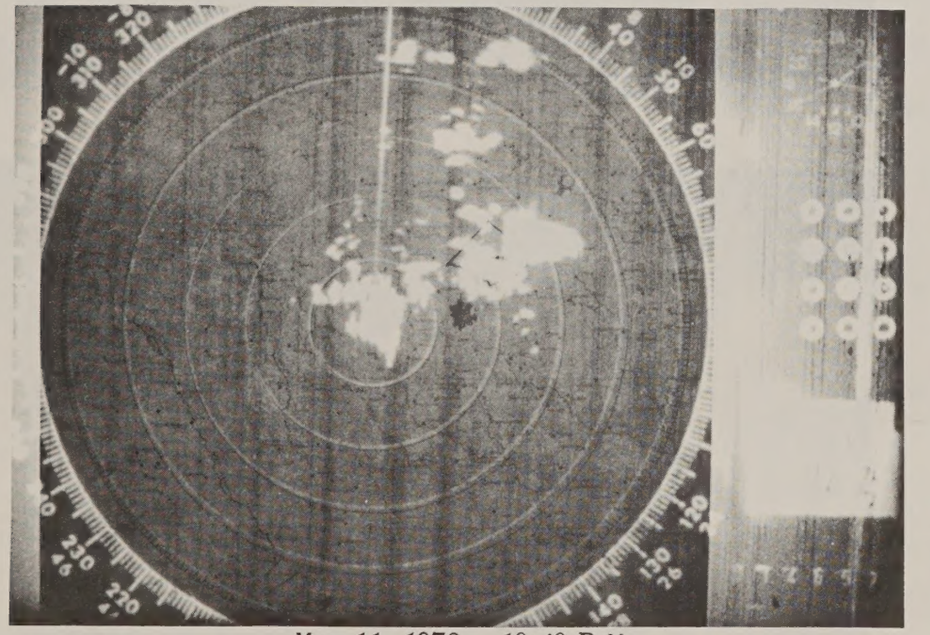
Courtesy National Weather Bureau, Department of Commerce



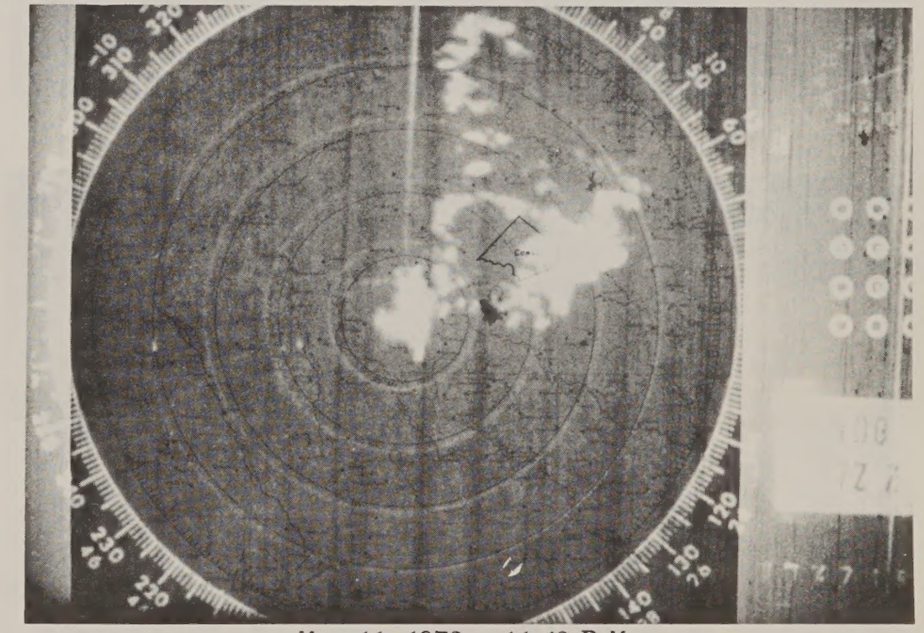
May 11, 1972 9:29 P.M.



May 11, 1972 10:02 P.M.



May 11, 1972 10:40 P.M.



May 11, 1972 11:42 P.M.

Figure 2

Hondo, Texas, Radar Pictures of Intense Rain Cells, May 11–12, 1972 New Braunfels Storm

Courtesy National Weather Bureau, Department of Commerce

LEGEND

- Watershed Boundary
- Drainage Area Controlled by Structure
- Area Benefited
- Floodwater Retarding Structure (Planned)
- Floodwater Retarding Structure (Existing)
- (8) Site Number
- 3 — Inches in Rainfall

N

0 1 2 3 4 MILES

APPROXIMATE SCALE
1:196,770

MAP COMPILED AT 1:126,720 AND REPRODUCED WITHOUT REGARD TO SCALE FOR MAXIMUM IMAGE ON SHEET.

Base – General Highway Map, 1970 Revision, Texas State Highway Dept. and USDC, Bureau of Public Roads.

Figure 3

ISOHYETAL MAP

(STORM OF MAY 11, 1972)

NEW BRAUNFELS AREA

IN

COMAL, HAYS AND GUADALUPE COUNTIES, TEXAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEMPLE, TEXAS

8-72 4-R-32123

8-72 4-R-32015

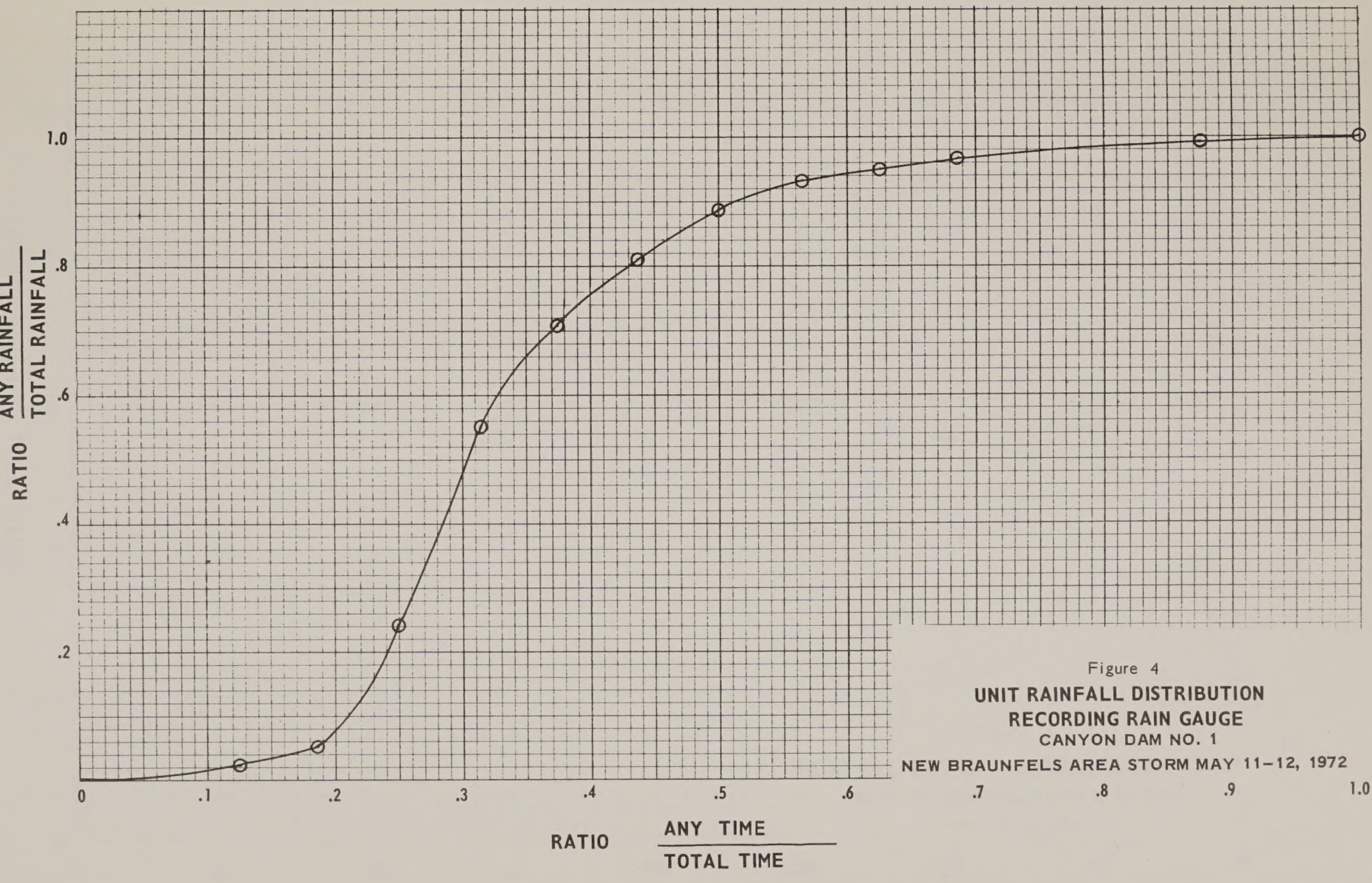


Figure 4

UNIT RAINFALL DISTRIBUTION
RECORDING RAIN GAUGE
CANYON DAM NO. 1
NEW BRAUNFELS AREA STORM MAY 11–12, 1972

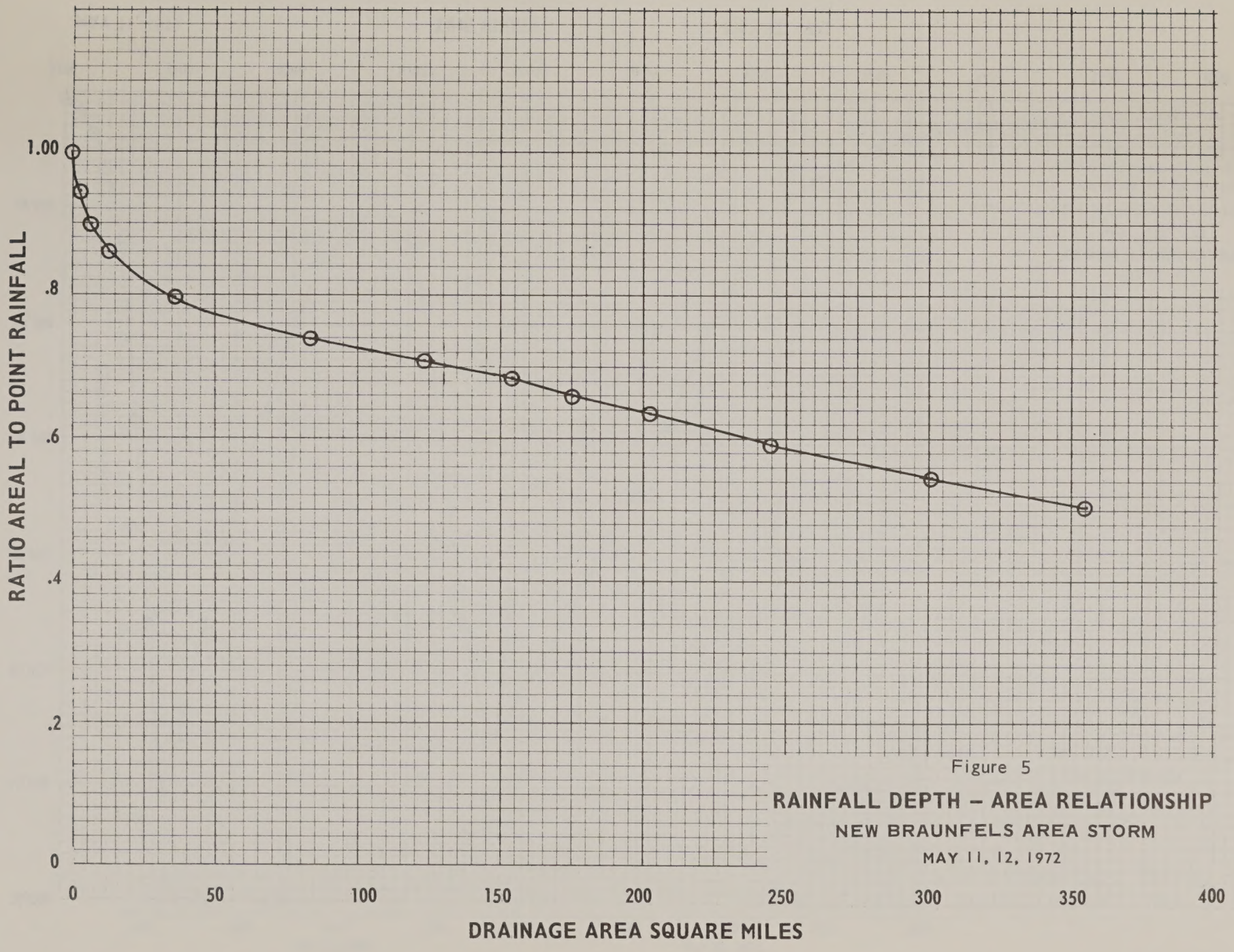


Figure 5

RAINFALL DEPTH – AREA RELATIONSHIP

NEW BRAUNFELS AREA STORM

MAY 11, 12, 1972

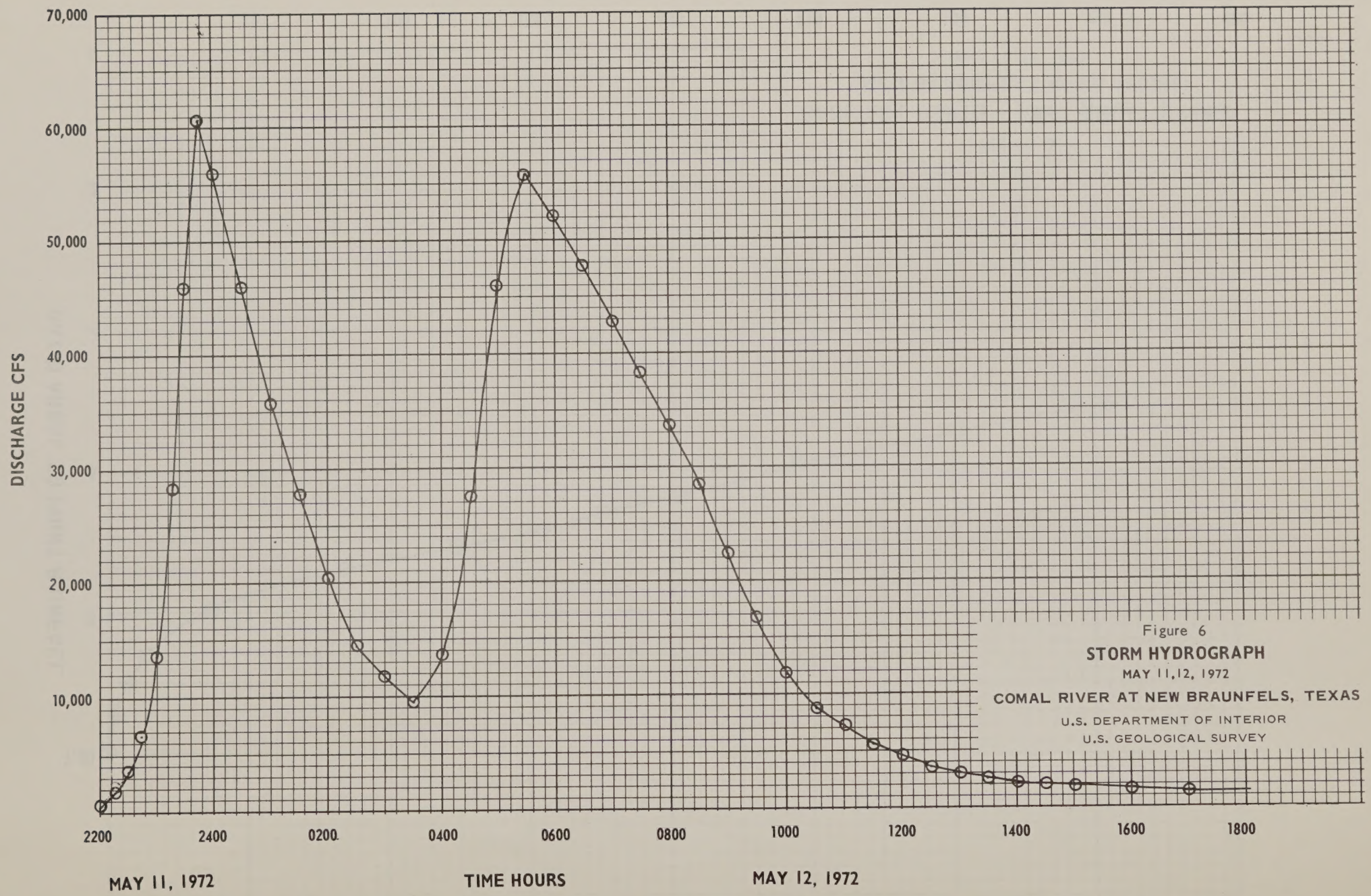


Figure 6

STORM HYDROGRAPH

MAY 11,12, 1972

COMAL RIVER AT NEW BRAUNFELS, TEXAS

U.S. DEPARTMENT OF INTERIOR

U.S. GEOLOGICAL SURVEY

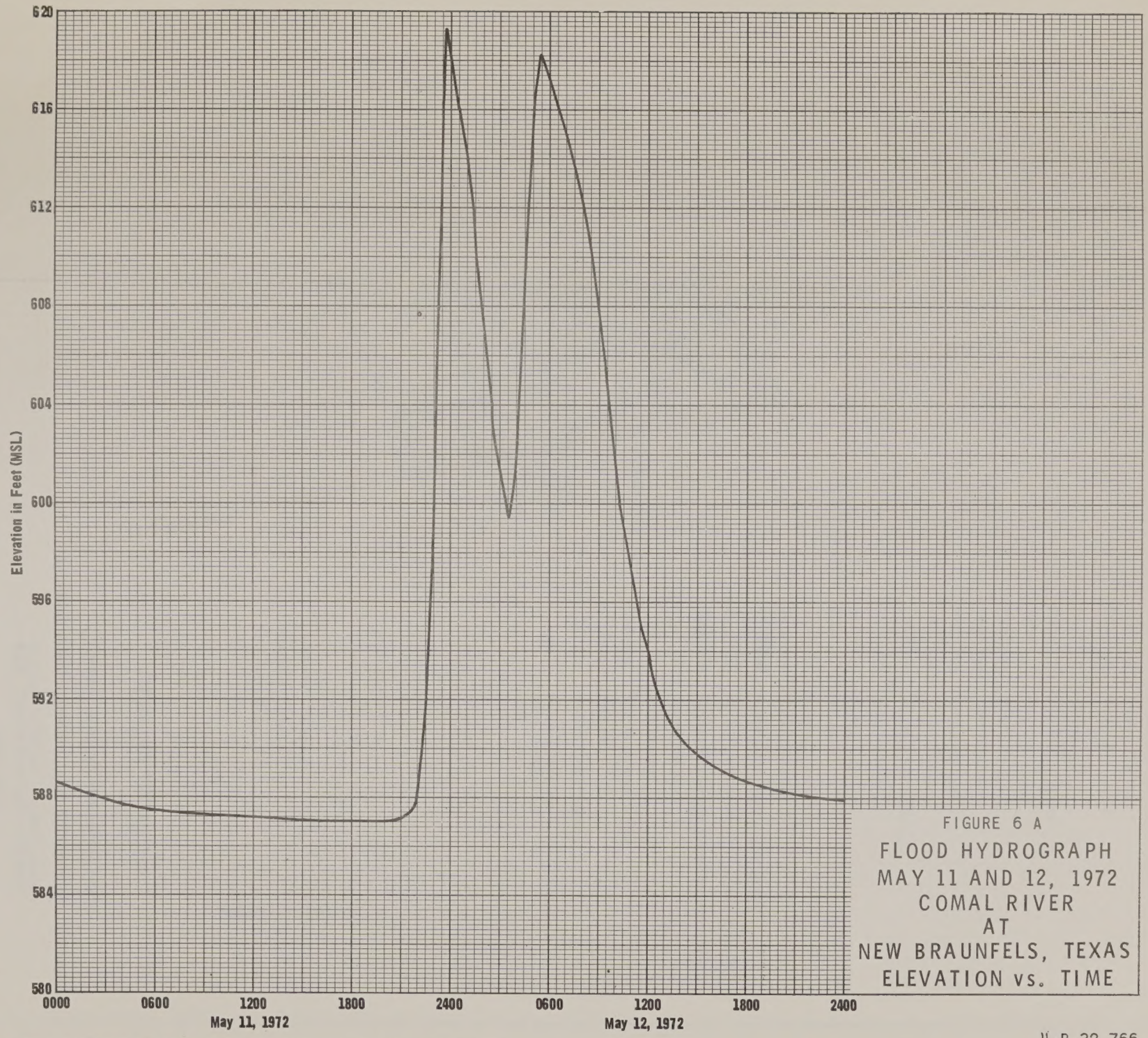


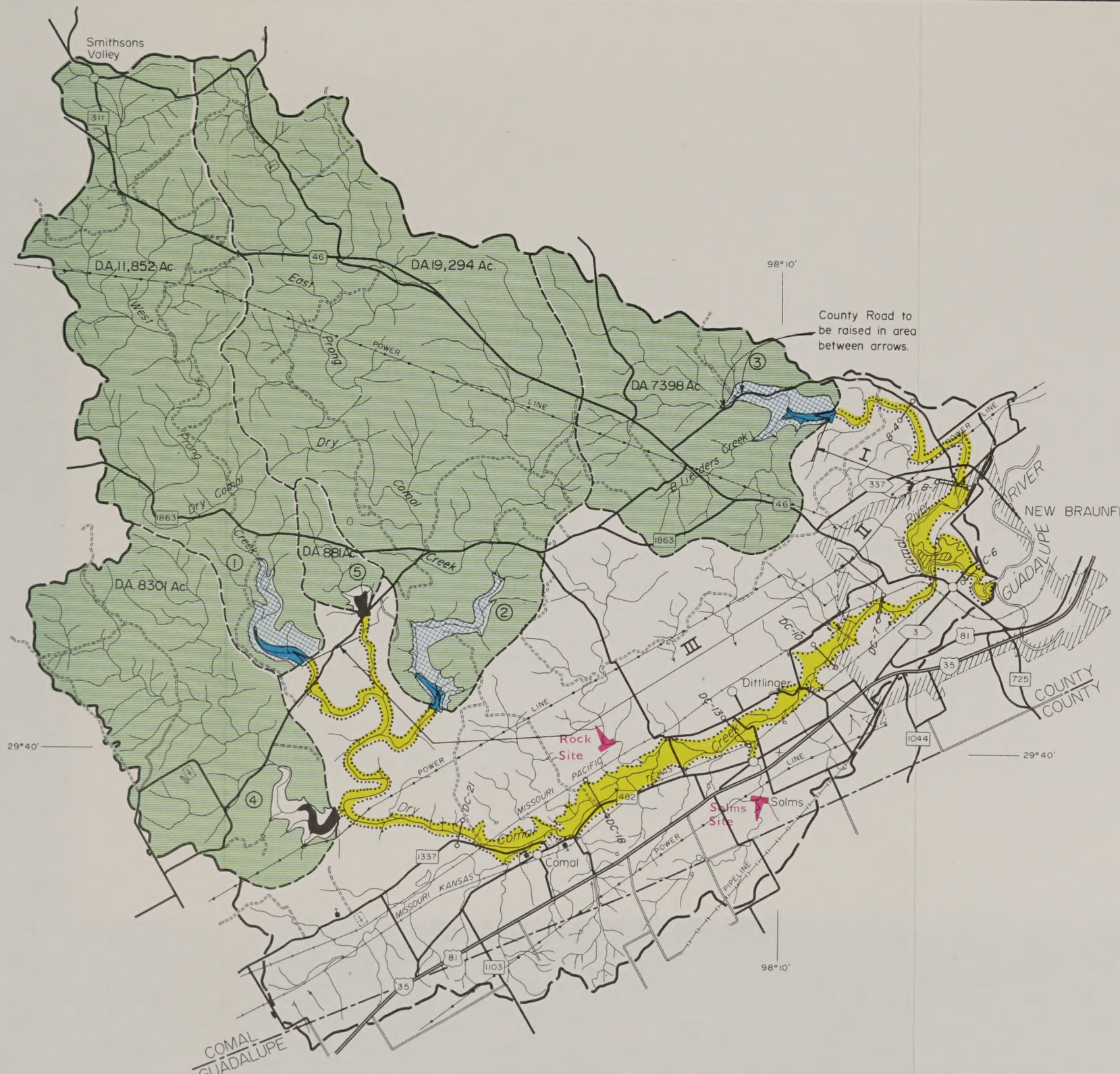
FIGURE 6 A

FLOOD HYDROGRAPH
MAY 11 AND 12, 1972
COMAL RIVER
AT
NEW BRAUNFELS, TEXAS
ELEVATION vs. TIME

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, Temple, Texas

4-R-32,766

USDA-SCS-FORT WORTH, TEX. 1973



LEGEND

- County Line
- City Limits
- Towns
- Railroad
- Unimproved Road
- Secondary Road
- Paved Road
- U.S. Highway
- Interstate Highway
- State Highway
- Farm to Market Road
- Loop or Spur
- Power Line
- Pipeline
- Drainage
- Watershed Boundary
- Floodwater Retarding Structure
- Floodwater Retarding Structure Existing
- Drainage Area Controlled by Structure
- Benefited Area
- ② Site Number
- DA 881Ac Drainage Area Acres
- I Reaches
- DC-5 Valley Cross Section
- Floodwater Retarding Structure Site Investigated

Figure 7

PROJECT MAP

COMAL RIVER WATERSHED

COMAL AND GUADALUPE COUNTIES, TEXAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
TEMPLE, TEXAS

0 1 2 3 4 5
APPROXIMATE SCALE - MILES

BASE COMPILED FROM LATEST USGS QUADRANGLES AND GENERAL HIGHWAY MAPS.
Approx. Area 83,200 Acres

10–72 4–R–32347
1–68 4–R–25737

USDA-SCS-FORT WORTH, TEX. 1973

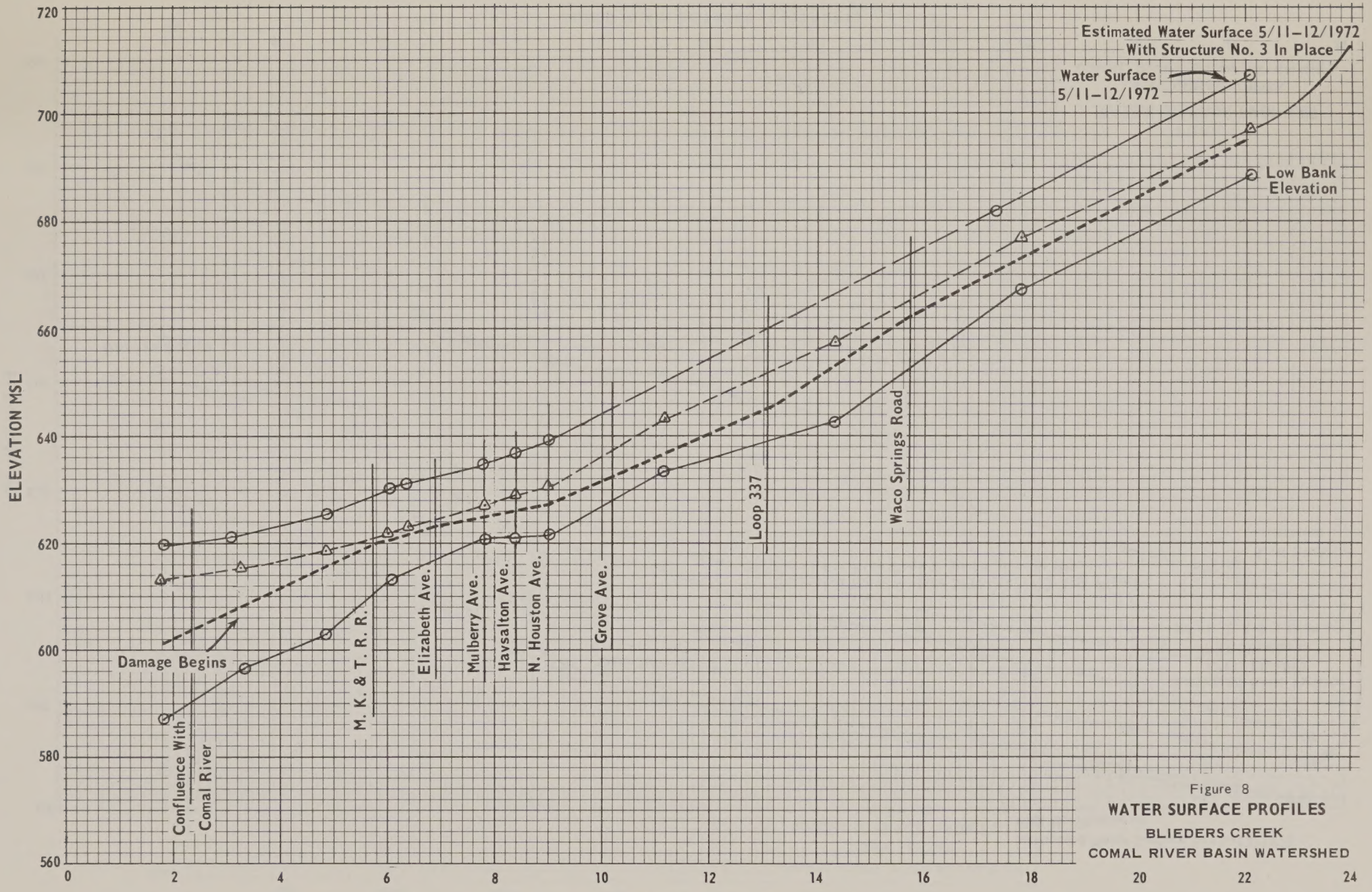


Figure 8

WATER SURFACE PROFILES

BLIEDERS CREEK

COMAL RIVER BASIN WATERSHED

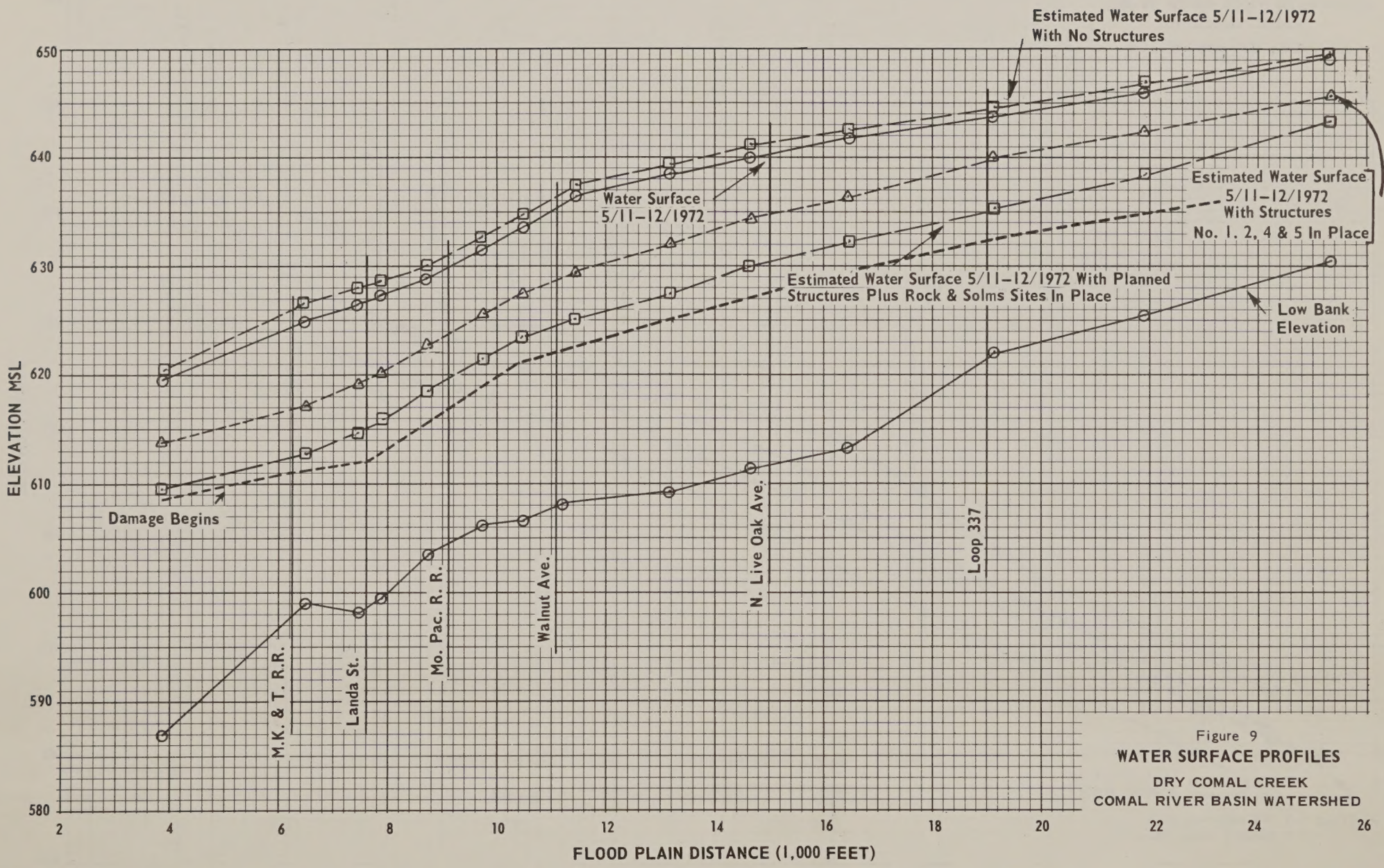


Figure 9

WATER SURFACE PROFILES

DRY COMAL CREEK

COMAL RIVER BASIN WATERSHED

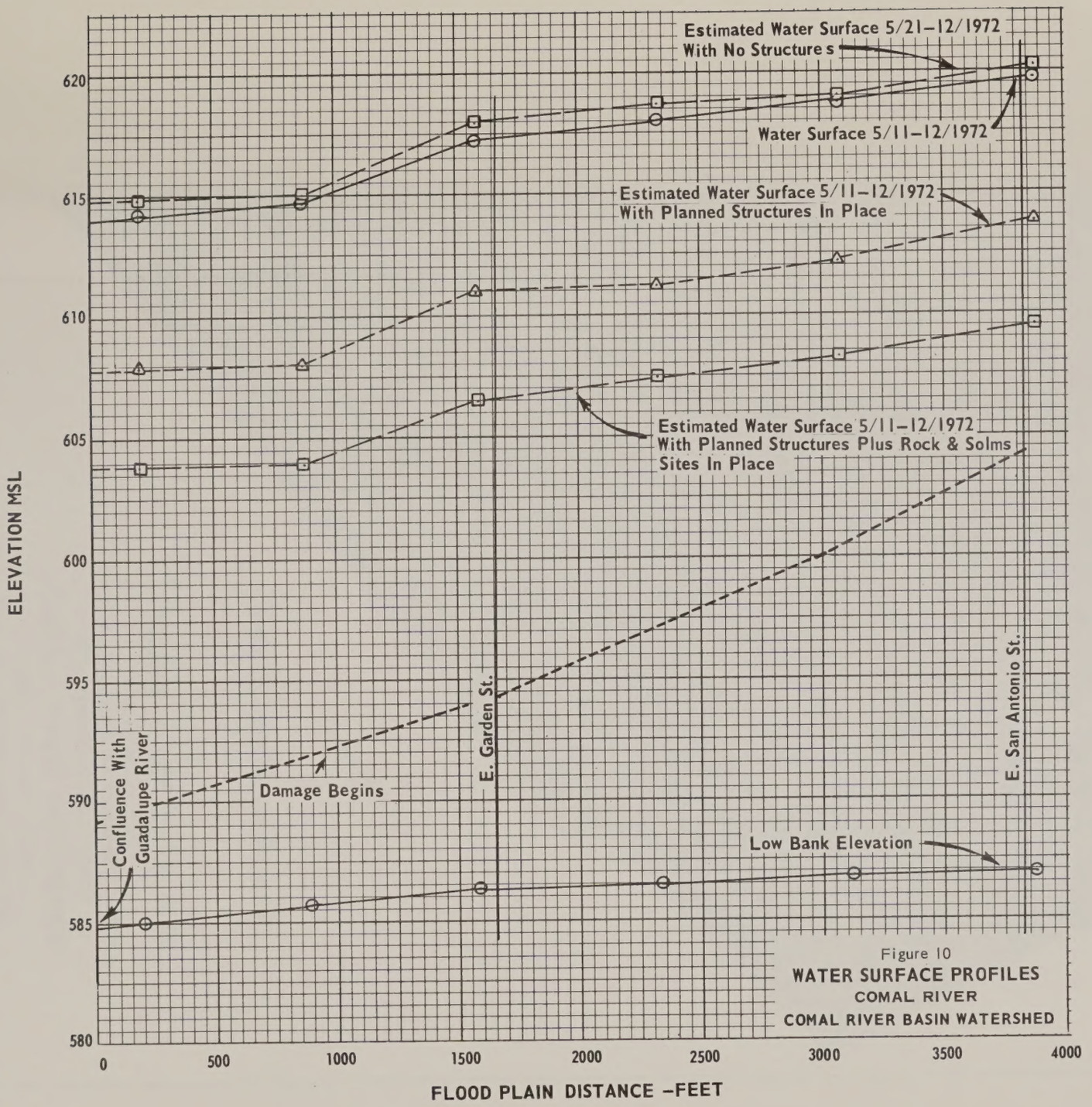


Figure 10
WATER SURFACE PROFILES
COMAL RIVER
COMAL RIVER BASIN WATERSHED

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE, TEMPLE, TEXAS

LEGEND

MAY 11-12, 1972 FLOOD

MAY 11-12, 1972 FLOOD WITH PROJECT

FIGURE 11

URBAN FLOOD PLAIN

COMAL RIVER PORTION

(MAY 11-12, 1972 FLOOD WITH & WITHOUT PROJECT)

NEW BRAUNFELS, TEXAS

COMAL RIVER WATERSHED

COMAL COUNTY, TEXAS

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

TEMPLE, TEXAS

Base - Area Photo Flights BQU 2JJ - 68, 103 & 105, 11-13-69

10-72 4-R-32,229

10-72 4-R-32,228

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE, TEMPLE, TEXAS

FIGURE 12

URBAN FLOOD PLAIN

GUADALUPE RIVER PORTION

NEW BRAUNFELS, TEXAS

COMAL RIVER WATERSHED

COMAL AND GUADALUPE COUNTIES, TEXAS

N

0 660 1320 1980 2640

SCALE IN FEET

APPROX. 1:15,840

BASE – AREA PHOTO FLIGHTS BQU – 2JJ-114, 116, & 118, 11-13-69

USDA-SCS-FORT WORTH, TEX. 1973

2-73 4-R-32,691

2-73 4-R-32,690

Debris Left After Flood

Typical Damage to Autos and Urban Area

Courtesy Mrs Frances Bridges, New Braunfels, Texas

Landa Park Damages

Aftermath of Flood

Courtesy Mrs. Frances Bridges, New Braunfels, Texas

Urban Damages in Landa Estates Area

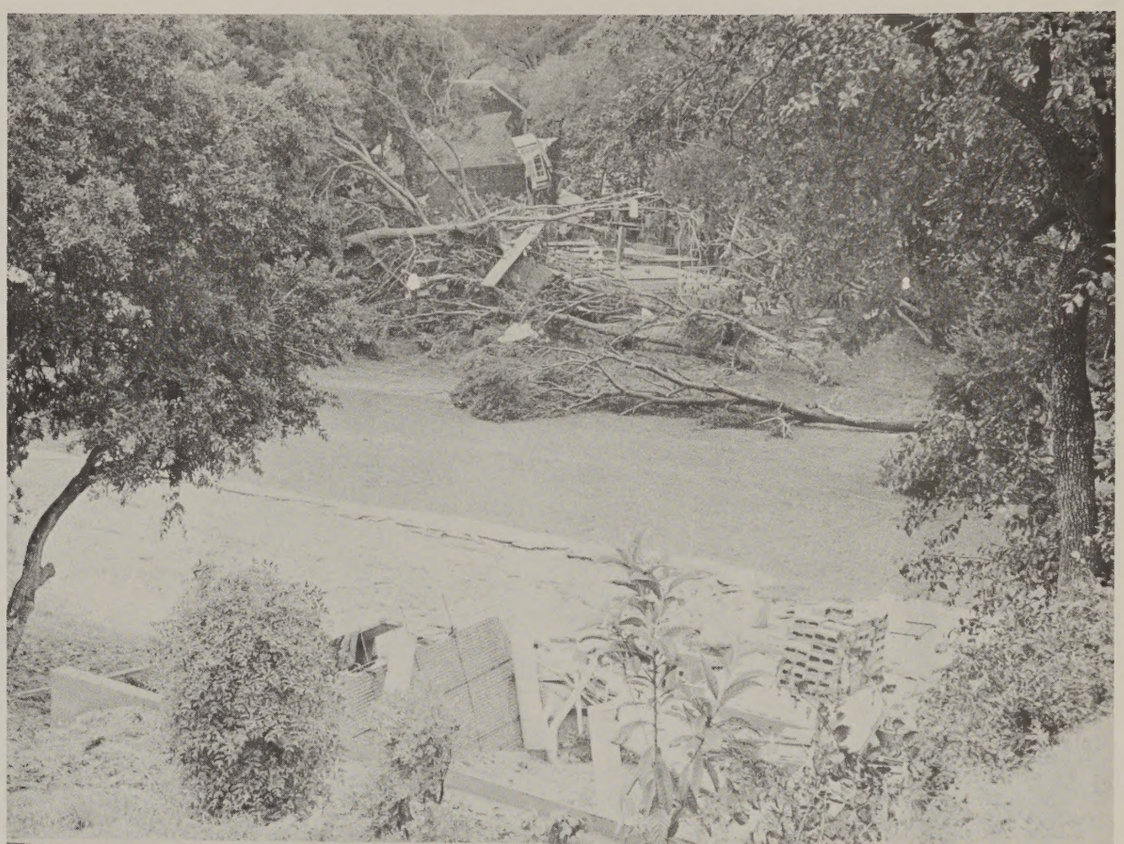
Home Destroyed on Guada Coma Drive

Courtesy Mrs. Frances Bridges, New Braunfels, Texas

Looking Downstream Along Edgewater Street (Note House in Street at Far End)

Urban Damages in Landa Estates Area

Courtesy Mrs. Frances Bridges, New Braunfels, Texas



Homes Destroyed by Flood, Guada Coma Drive West

Damage to City Streets and Bridges (Note Broken Sewer Line on Bridge)

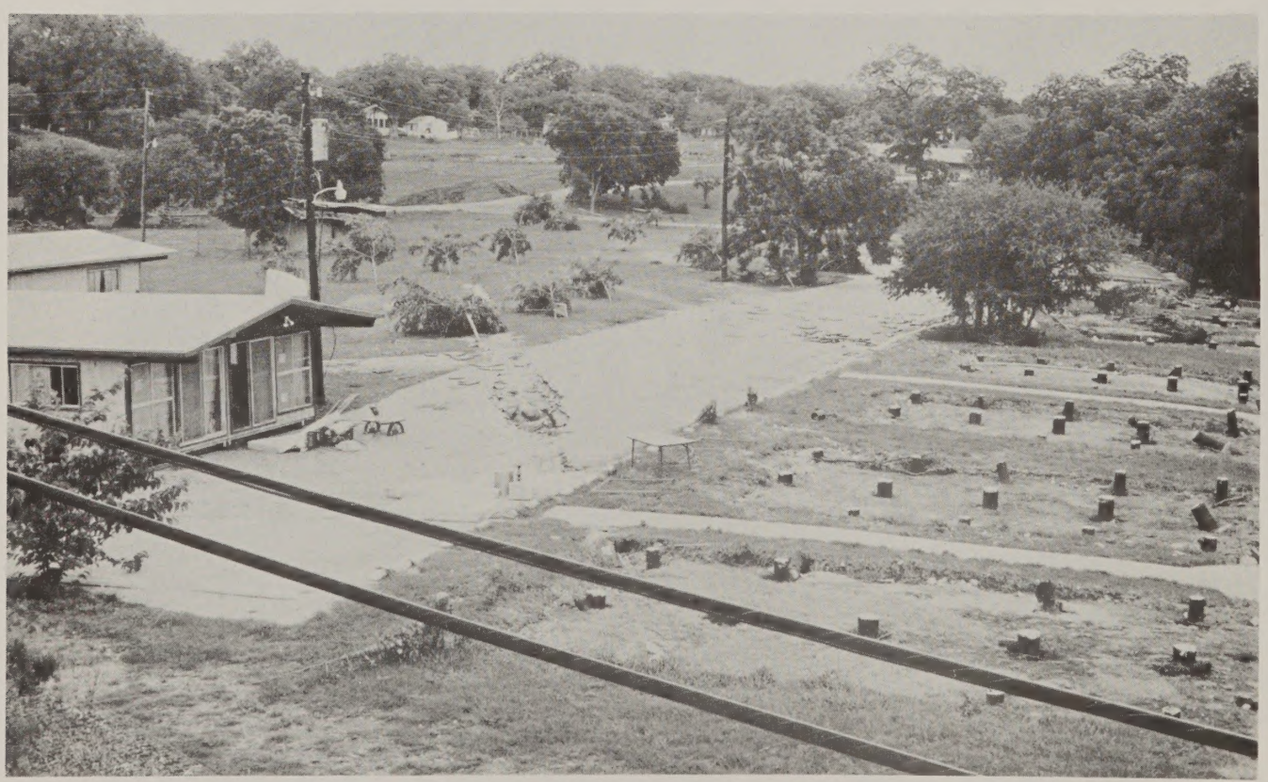
Courtesy Mrs. Frances Bridges, New Braunfels, Texas

Grain Car Overturned

Broken Sewer Line Dumping Raw Sewage into Comal River

Courtesy New Braunfels Herald

Urban Damages–Landa Estates Area



Resort Cabins Swept Away–(Note Path of Cabins by Bent Small Trees)

Courtesy New Braunfels Herald

Aerial View of Blieders Creek Above New Braunfels After Flood – Highway is Loop 337 (Note Scour by High Velocity)

Blieders Creek Back to Normal After Flood–Below Loop 337 (Note Scour by High Velocity)

Courtesy New Braunfels Herald

FLOOD CONTROL FILES
old files

FLOODS-FLOOD CONTROL

FLOOD CONTROL

Floods are normal phenomena. Such being the case one's final thought is that man would arrange his civilized institutions and developments accordingly. Largely to the extent that he conforms his relationships to those of Nature will the permanency of his civilizations depend. But in a country where individual initiative is given freedom bordering upon license, it is not only a case of many men, many minds, but also many memories, mostly short. Some are so very short that many areas in floods plains throughout the country hardly become dry after a severeflood before they are again occupied as though similar overflows would never recur.

One important characteristics of floods is that in each separate stream they occur in greatly varying magnitude, the more severe, the more infrequent. Due to the natural phenomena which produce them, the relation between flood magnitudes and frequencies may be treated by statistical methods. The observation periods on many important streams of the country is sufficiently long to estimate with some degree of assurance the magnitude of floods which may occur on an average of once in 5 years, in 10 years, in 50 years, in 100 years, etc.

This ability to anticipate what may occur is quite important, but its practical value would be vastly more were it not for the fact that a 100-year flood may occur next year and a 90-year one the next following year.

Generally speaking flood control to almost any desired degree is possible. Often, however, it is not economically justifiable, and

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old file

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usually it would have been wiser in the first place to insist upon developments and social institutions being outside normally overflowed areas. There are, however, numerous local conditions which must be recognized, such as industrial plants encroaching on flood plains of rivers. Most of these should never have developed, but nevertheless they have, and moreover, some have developed to such degrees that even heroic flood control measures constitute the lesser of existing evils. It is important to view flood control throughout the country as a whole from this standpoint in order to visualize the matter in its proper relation to other features of national water use.

Generally speaking flood control works are of three types,

a. Detention reservoirs to hold back the peaks of floods for later release.

b. Retarding basins, to automatically retard and smooth out flood peaks.

c. Increasing channel capacities.

d. Barriers and levees to keep areas free from overflow.

Often all these types are resorted to in aggravated cases.

The first is the most satisfactory but unfortunately it is not always feasible, and often is very expensive. Indeed it is often so expensive as to be quite impracticable. Important exceptions are the Boulder Dam development on the Colorado; the Roosevelt on the Salt, and the Coolidge on the Gila. These combined will reduce 200-year flood flows to less than yearly ones. The total cost, if chargeable to flood control, would have been fantastic; some $75,000,000 to

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A good example of the retarding basin method is the Miami (Ohio) Conservancy District. Although extensive channel improvement and levee work was done, about half of the cost was for five retarding basins of such capacity that, together with the improved channels, they furnish complete protection to the communities within the district.

The channel improvement method is seldom used entirely by itself in a flood control project, although it usually has a place in almost any such project. A certain amount of increased channel capacity can usually be secured at low cost. To carry this method very far, however, usually involves the taking of valuable property, especially through settled communities, where industrial developments often have encroached on the overflow channels.

The levee method is the traditional flood control method and is the one now being generally used on the lower Mississippi. This form of protection has the advantage of being direct and visible, and the levees serve as a standing warning against the occupancy and use of the portion of the flood channel which remains exposed.

In certain sections of the country, where storage for irrigation or power has resulted in fairly complete development of some river

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Works designed primarily for other purposes may often be adapted to flood control also, but generally speaking, it is only when special provision has been made against the maximum flood producing possibilities of a river system, that safety should be assumed.

The inter-relation of floods, silting, and erosion control should be mentioned. In those areas where soil erosion is acute, notably in the southern part of the country, a large propertion of the total annual flow may come down in a few floods. These carry heavy burdens of eroded soil, depositing it in river beds and reservoirs, causing serious injury to channel capacities and storage volume. The economic loss from this aspect of floods flows is of large proportions, and is to some extent preventable by erosion control measures.

Following is a brief summary of flood problems in the principal drainage areas of the country:

North Pacific Drainage: Flood damages in the North Pacific Drainage are confined largely to the region west of the Cascade Mountains. Here thirty six streams, including the lower Columbia River are recorded as subject to destructive floods. Complete figures on average annual damages are not available, but the total property damage caused by the last flood on 24 streams is calculated at about $11,424,000. Frequencies of destructive floods range up to 12 years.

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South Pacific Drainage: The major existing flood problems in this area are found in the San Joaquin-Sacramento Basins, where the floods of 1907, 1909, and 1911 inflicted a total damage of some $10,000,000, and in Los Angeles County, where flood damage has been serious. No figures are available on average annual losses.

In the San Joaquin Basin, about 800,000 acres of land have been inadequately protected by levees. Along the Sacramento River, a well developed protection plan has by now been about 85% completed and will afford adequate protection when it is finished.

The Sacramento-project, consisting of levees and by-pass floodways, is one of two major flood control projects in the region. The other is found in the Los Angeles County Flood Control District, where the solution has been sought by providing detention storage to decrease volume of peak flow, - the surplus runoff being partially conserved through direction to underground storage by means of spreading works.

On the American River a levee and by-pass project is now 95% completed, while on the Santa Ana, some work has been done on debris dams, levees and spreading works.

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Southwest Mississippi Drainage: Approximately seven million acres of land east of the 99th meridian are subject to destructive floods in this district, caused by heavy spring rains.

More than 2,000,000 acres of land have levee protection at present, but the levees, constructed in an unplanned manner, are inadequate in nearly all cases.

Projects are now under consideration to provide further levee protection for some 700,000 acres of land and a number of communities, and to give complete or partial protection to land along a number of rivers by means of multiple-purpose reservoirs.

Missouri River Drainage: About 2,275,000 acres of farmland and some 26 municipalities in the Missouri Basin are subject to destrcutive floods causing an average annual direct loss of about $2,800,000. The flood hazard is localized in the headwater areas where ice-jams are largely responsible, and in the Kansas-River-Lower Missouri Area, where spring rains cause heavy flood-damages.

Approximately 1,200,000 acres of land and a number of communities now have levee-protection that is largely inadequate. Further protection of rural lands is not deemed economically feasible, but the protection, generally by means of levees, of some thirteen communities of various sizes, is considered feasible.

Protection by means of reservoirs seems at present possibly feasible only in the case of Kaw River lands.

Upper Mississippi Drainage: The most damaging floods in this drain-

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Upper Mississippi Drainage: The most damaging floods in this drain-

age are those which occur during the late spring and early summer in the southern half of the area. The flood hazard on the Wisconsin and upper Mississippi rivers has been almost eliminated by regulatory works. On other streams, notably the Illinois River, where the average annual damages exceed $2,000,000, the levees of agricultural drainage enterprises have so constricted the channel that the height of flood flows has been increased greatly and the levee system has proven entirely inadequate.

Lower Mississippi Drainage: Most of the 40,000 square miles or more of alluvial land of the lower Mississippi River was subject to occasional flooding from the main stream or its tributaries when the first levees were built in 1717. A $300,000,000 levee system now limits Mississippi flood waters to the main channel and about 8,000 square miles of backwater lands at the mouths of tributaries. At times of very high flow, roughly once in thirteen years, an additional 4,000 square miles of floodway land will be imundated in order to prevent a repetition of the breaking of main stem levees which caused damages in excess of $250,000,000 in 1927. Approximately 2,340 square miles in the Yazoo River Basin, 2,125 square miles in the St. Francis River Basin, and 2,000 square miles in the White River Basin are flooded on an average of once in five to fifteen years and cause an average annual damage of at least $3,500,000. No protection is afforded to some of this land, but much of it is served by inadequate and poorly coordinated levee works which commonly give way at times of very high water.

Western Gulf Drainage: Destructive floods occur in the coastal plain reaches of the major streams in the Western Gulf Drainage on an average of once in four or five years. In 1921, 172 lives and property valued at $5,500,000 were lost in the Brazos Basin. Levee districts

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have been formed on a number of these streams, and in a few places, notably San Antonio and Fort Worth, single or multiple-purpose reservoirs have been constructed. Irrigation and power reservoirs on the upper reaches have acted to reduce some flood flows, but have little or no effect on runoff from many of the heavy storms which are restricted to the coastal sections.

Ohio River Drainage: Floods of average intensity do relatively little damage in the Ohio Basin. At intervals of from 25 to 100 years, however, this Basin experiences terrific floods which cause serious property damage, and, in some cases, loss of human life. In addition to its local effect, the Ohio ranks as the major flood producing tributary of the Mississippi.

Control of these great floods is made difficult because of their magnitude (1,000,000 - 1,500,000 C.F.S.) and because the land adjacent to the main stem is occupied by cities, factories, and farms. Vast retarding basins, therefore, probably are not practicable on the Ohio River proper, and flood control works may have to be restricted to dams on the tributaries and levees along the major streams. More than $40,000,000 have been spent by local interests to construct partial or complete flood control works in widely distributed parts of the Ohio Basin. Fifteen reservoirs recently authorized, and 13 others that appear to be feasible, would have a considerable effect on Ohio River floods, and would also result in a large measure of local protection.

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Red River, Great Lakes and St. Lawrence Region: Much agricultural land and a few towns in the nearly flat, lacustrine plain of the Red River Basin are subject to flooding from the main stem and tributaries during the spring, and particularly at times when discharge is retarded by ice in the channels to the north. Although no truly severe floods have occurred since 1882 and 1897, a flood of moderate height occurred in 1916, and more severe ones may be expected. Proposals for flood control work have received little study during the recent period of dry years.

Floods cause occasional damage on a few reaches of the Great Lakes tributaries in the glaciated lowlands of Wisconsin, Indiana, Michigan, and Ohio. Most of the affected towns and cities have met the problem by constructing local channel improvement works, as at Milwaukee and Grand Rapids, but a few urban areas and many agricultural areas remain unppotected.

In the minor Great Lakes drainages of Vermont and New York severe falls floods and a menace to bridges and buildings which restrict unduly the channels in the valley bottoms. Some of the valleys are now protected in part by power reservoirs. The area of most serious flood damage, the Winooski Valley, has recently been given protection through the construction of two detention reservoirs by C.C.C. labor.

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North Atlantic Drainage: Storms of the intensity of that which caused the great New England flood of 1927, and with an average frequency of about 100 years, are possible throughout almost all of this area. Physiographic conditions are conducive to the development of strong flood flows in most New England and New Jersey drainages, and on the Hudson River above Albany. On the Susquehanna River ice jams have caused very high waters. Damages experienced in the relatively narrow valleys have amounted to as much as $10,000 per square mile of the drainage area of the river. On some New England streams, such as the Deerfield River, flood flows are absorbed in large measure by storage reservoirs for power or water supply. On other streams, such as the Connecticut River, municipalities have constructed levee systems for local protection. In general, however, flood protection has received little direct attention.

Eastern Gulf and South Atlantic Drainage: Much of the land subject to flooding in this region lies on the gently sloping coastal plain, although the larger floods cause material damage in the Piedmont areas, and sometimes in the Mountain regions. A good deal of the land in the lower reaches of the major streams is swampy, and a considerable portion of the valley bottoms upstream is subject to flooding which commonly occurs in the South Atlantic drainages in the fall, and in the Eastern Gulf drainages in the spring. Only a few urban areas are menaced by high water, and most of these are adequately protected by channel improvement and levee works. A major exception is Augusta, Georgia which is in danger of flooding from the Savannah River. The expense of

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protecting the cultivated or tillabel lands is so great that it is justified in only a few places. Hurricane tidal waves on Lake Okeechobee, Florida constitute the outstanding flood hazard in the whole region, and their damaging effect is now being reduced by levee construction at a cost of $17,000,000.

Rainfall, Runoff, and Flood Frequency Studies: In order to plan intelligently for flood control and flood protection works for any locality it is necessary to secure and study all of the facts which can be found relating to the frequency and magnitude of past floods in the region concerned. Although many scattered and fragmentary records have been preserved of floods which have occurred in the past great enough to cause serious damage, no complete compilation exists anywhere of all such data in such form as to be available for general consultation and use. In many regions such records as do exist cover too short a period of time, and are too scanty, to afford a reliable estimate of the frequency of occurrence of floods of different sizes, and to reveal the size of the greatest flood that may occur sometime in the future and against which protection should be provided. In such cases it is necessary to consider the flood history of neighboring and similar areas and apply to the region under consideration conclusions drawn from such histories.

Since in many cases rainfall records are much more complete than data concerning past floods, it is customary also to study rainfall data in the endeavor to learn from them something regarding the size and frequency of floods that may be reasonably expected to occur

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in the future. Numerous attempts have been made in the past to deduce a definite numerical relation between heavy rainfall records and the dimensions of the floods resulting from the rainfall, but no one hitherto has had the time and means needed to unravel all the effects of the numerous factors that affect this relationship.

It seemed opportune, therefore, to the Mississippi Valley Committee in the early stages of its work to attempt to further the use and control of the water resources of the country by initiating a comprehensive compilation and study of existing flood records, and a new attack on the problem of discovering a workable procedure for deducing runoff characteristics from rainfall records. An allotment of $45,000 was secured from the Public Works Administration and the work was entrusted to the staff of the U. S. Geological Survey. Advice as to methods of procedure has been obtained from committees of the American Society of Civil Engineers and the American Geophysical Union. The work has been thoroughly organized and encouraging progress has been made to date. By the end of the fiscal year these initial studies will have been completed. It is planned to have the results published promptly. The work will illustrate the results that can be obtained from a widespread cooperative effort to extend the limits of our scientific and technical knowledge in a field much needed for the more efficient control and use of water. The need for the continuing compilation of records and further technical

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